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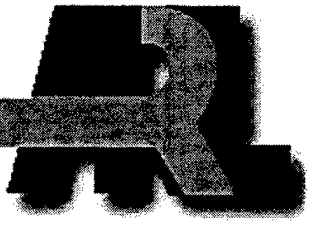

Initial Evaluation of the CTA International 40-mm Cased Telescoped Weapon System

Timothy G. Farrand

ARL-TR-2275 AUGUST 2000

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Abstract

The capability of off-the-shelf medium caliber ammunition has been advertised extensively. As the decision about the main armament for imminent medium caliber platforms approaches, more definitive independent analyses of the advertised systems are being conducted. To increase the current database, an evaluation of the 40-mm cased telescoped weapon system (CTWS) was coordinated between the U.S. Government and CTA International (CTAI), a French-United Kingdom company. The emphasis of this evaluation was the performance of the armor-piercing, fin-stabilized, discarding sabot (APFSDS) projectile. In addition, the pressures inside the Bradley fighting vehicle, where the CTWS was mounted, and shock measurements on the exterior of the vehicle were taken to estimate the effect of the weapon system on the vehicle and the crew. The evaluation of the terminal effects of the APFSDS against selected Senior National Representatives (SNR)-defined range targets is documented in a separate, classified version of the evaluation.

The APFSDS ammunition performed as advertised, with a muzzle velocity of approximately 1640 m/s and a velocity decay of 0.12 m/s/m. These values give the 40-mm CTAI APFSDS a high velocity at the target for typical engagement distances. The measured shock to the vehicle and overpressures within the vehicle during firing all appear to be at acceptable levels for these initial tests.

ACKNOWLEDGMENTS

The author would like to thank the Project Manager-Tank and Medium Caliber Armament Systems (PM-TMAS) for funding this program and coordinating the efforts with CTA International (CTAI). He would also like to thank the representatives from CTAI, primarily Mr. Mike Duckworth, Mr. Richard Braddock, and Mr. David Leslie. The CTAI crew that supported the effort also performed a magnificent job of preparing the gun for operation, mounting it in the Bradley fighting vehicle, and training the Aberdeen Test Center (ATC) staff for the demonstration; the crew's efforts are very commendable. Finally, the author would like to extend his sincere acknowledgments to the crew at ATC. They performed an excellent job of completing the CTAI evaluation and demonstrating the ammunition. Ms. Hazel Cassady and Mr. Joe Zelik, the test directors at ATC, did an outstanding job of organizing the effort and having the program performed without any problems.

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INITIAL EVALUATION OF THE CTA INTERNATIONAL
40-MM CASED TELESCOPED WEAPON SYSTEM

1. Introduction

1.1 Overview

The capability of off-the-shelf medium caliber ammunition has been advertised extensively. As the decision about the main armament for imminent medium caliber platforms approaches, more definitive independent analyses of the advertised systems are being conducted, based on available data. To increase the database, the evaluation of the 40-mm cased telescoped weapon system (CTWS) was coordinated between the U.S. Government and CTA International (CTAI), a French-United Kingdom (UK) company. The emphasis of this evaluation was the armor-piercing, fin-stabilized, discarding sabot (APFSDS) projectile. This evaluation is similar to one conducted for the 35-mm Rheinmetall APFSDS (October 1998) in a similar cooperative program. The evaluation culminated in a one-day demonstration to present to the users, namely, the U.S. Army Infantry Center, U.S. Army Armor Center, U.S. Marines, and other Government organizations, that is, the Office of the Secretary of Defense, Tank-Automotive Command (TACOM), Armament Research, Development, and Engineering Center (ARDEC), Army Materiel Systems Analysis Activity, Army Evaluation Center, various project managers, etc., the capability of the 40-mm CTAI ammunition against current threats.

The Program Manager for the Tank and Medium Caliber Armament Systems (PM-TMAS) sponsored the evaluation. The U.S. Army Research Laboratory (ARL) and the Aberdeen Test Center (ATC) at Aberdeen Proving Ground (APG), Maryland, performed the evaluation in October through November 1999, with the actual demonstration on 3 November.

The program was divided into two evaluations; the first evaluation characterized the APFSDS ammunition performance against Senior National Representatives (SNR)-defined range targets, and the second evaluation investigated the integration of the CTWS in the Bradley fighting vehicle (BFV). Because of the release restrictions and classification of the data from the two evaluations, the documentation will also be separated into two reports. This unclassified report addresses the details of the system characteristics. A separate, classified report will address the terminal ballistic characterization of the APFSDS.

1.2 Background

Mr. Mike Duckworth, a representative from CTAI, supplied the following background information about the CTA system and the CTAI Company.

Program History

The CTWS development program, which began in 1997, was preceded by a technology phase, which lasted 3 years. This initial program phase was conducted in conjunction with the UK Defence Evaluation and Research Agency (DERA) and the French agency SPART (*Service des Programmes d'Armement Terrestre*). This technology work was conducted in 45-mm caliber initially (following the U.S., UK, and French agreed-upon 45-mm CTA standard North Atlantic Treaty Organization [NATO] agreement [STANAG]); it changed in 1997 to 40 mm. At the end of this phase, DERA reported CTA technology as low risk. CTAI is now in the fourth year of its full development program, which is due to be completed in early 2002.

Scope of Program

From the beginning, the product that is being developed is a complete weapon system. The design activities conducted at CTAI's facilities cover the weapon, ammunition-handling system, and ammunition, including APFSDS, general purpose (GP) rounds, and target practice-tracer rounds. The scope and tasks defined within the CTWS development program are closely aligned with the UK Tactical Reconnaissance Armored Combat Equipment Requirement (TRACER) and with the U.S. Future Scout and Cavalry System (FSCS) program definition.

System Description

Weapon

The weapon weighs 218 kg, and its compact size (by virtue of the unique rotating chamber functionality) gives it a swept volume of only 74 liters for an arc of -10 degrees to +35 degrees. A photograph of the gun is shown in Figure 1.

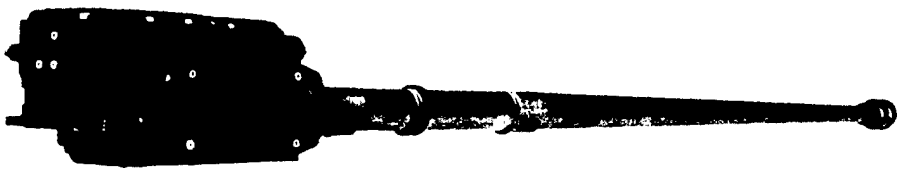

Figure 1. 40-mm CTWS Weapon.

The simple cylindrical shape of the CTA cartridge simplifies the cannon by virtue of the "push-through principle" of operation; its compactness and modularity foster elegant integration solutions. The principle of the weapon function is shown by the graphic in Figure 2.

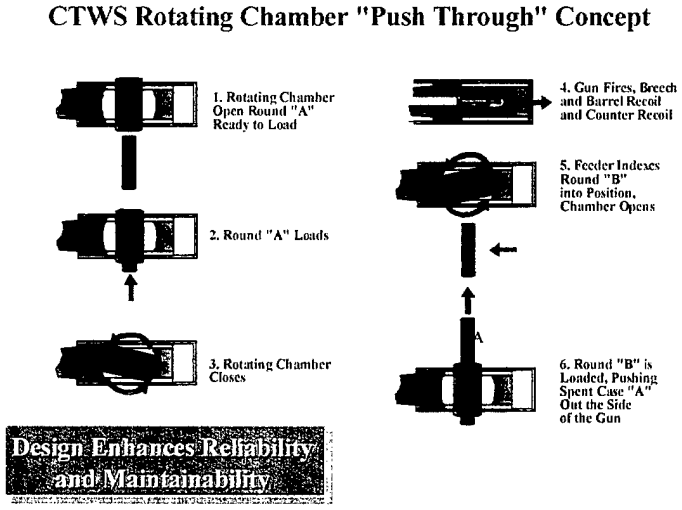

Figure 2. "Push-Through" Principle of 40-mm CTWS Weapon.

As demonstrated in this evaluation, the CTWS gun is compact enough to be installed in an existing BFV (see Figure 3).

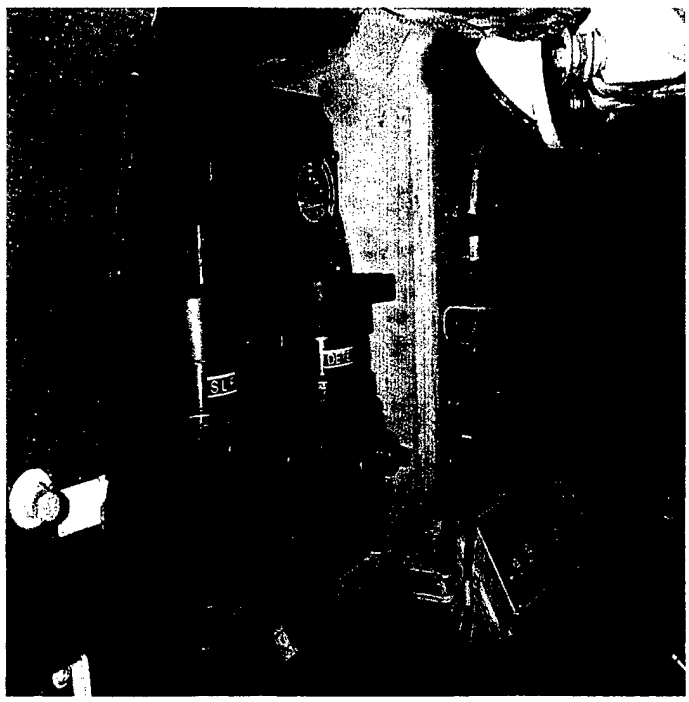

Figure 3. 40-mm CTWS Integrated in BFV Turret.

Additionally, computer-aided design (CAD) analysis has been employed to demonstrate how the entire CTWS, feed system, and ammunition storage can be integrated into the current BFV. A complete 105-round mission load, linkless feed system has been produced and demonstrated by CTAI during mock-up conditions. This feed system fits in the same area within the BFV that is occupied by the current 25-mm Bushmaster weapon system. This is shown in Figure 4.

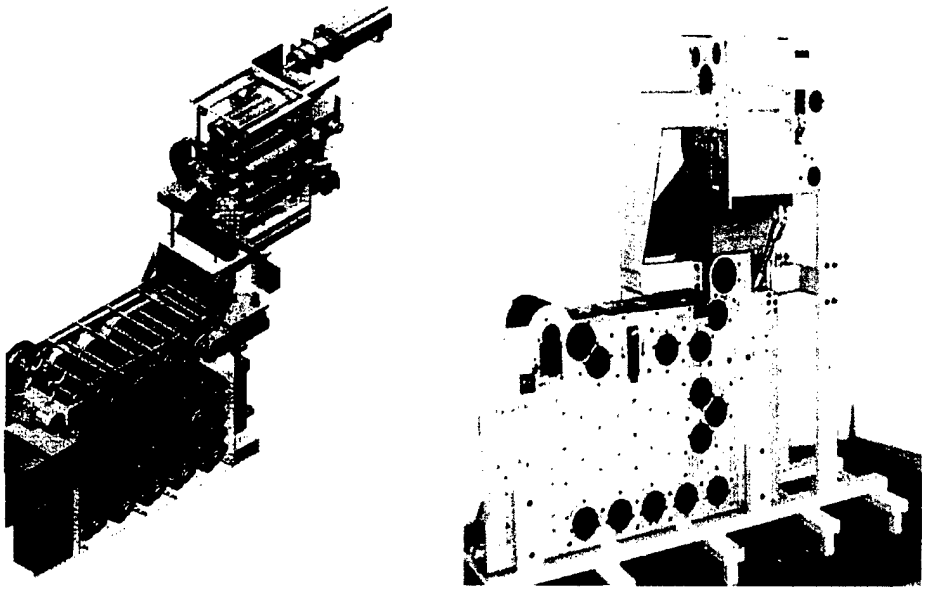

Figure 4. 105-round Linkless Feeder for BFV.

Projectile Characteristics

The APFSDS round currently being developed follows the conventional cased telescopic ammunition (CTA) concept in which the projectile is positioned inside the cylindrical cartridge case and inside the propellant. This is shown in Figure 5. The resulting 40-mm CTA round is half the length of a conventional 40-mm cartridge manufactured by Bofors Precision Machining, Inc. The projectile follows the classic concept in many ways, as it consists of a tungsten alloy penetrator, an aluminum sabot, and a slipping obturator. The penetrator is maintained in a stable flight by a steel fin fixed to the rear. A tracer has been added inside the fin unit. The penetrator core is a classic tungsten alloy monoblock cylinder, as seen in Figure 6.

Front **Rear**

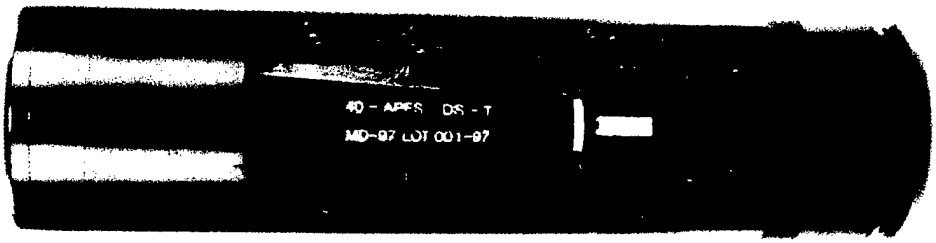

Figure 5. 40-mm CTWS APFSDS Cartridge in Section.

Figure 6. 40-mm CTWS APFSDS Penetrator.

The penetrator is threaded along a significant length of the penetrator to provide the driving interface with the aluminum sabot, and a smaller finer thread is added at the rear to attach a stabilizing fin unit. The APFSDS propellant is a standard single base loose grain propellant charge (BTU7). The propellant is NATO qualified and already in service in a number of European medium caliber weapon systems. The sabot is a "pull" sabot rather than the more conventional "push" saddle-type sabot as used in conventional APFSDS ammunition. Apart from this difference, the technology can be considered standard engineering. The sabot design has been optimized to provide the maximum amount of stability to the projectile inside the gun barrel, while keeping its mass to a minimum. The fin unit is a classic four-bladed steel fin. A small conventional tracer canister is screwed into the rear of the fin unit. Obturation is obtained by a Nylon slipping-driving band assembled over the sabot.

Table 1 lists the physical parameters of the CTAI APFSDS. Also shown are the advertised muzzle velocity and velocity decay.

Table 1

The Physical Parameters of the CTAI APFSDS Projectile

Projectile		Penetrator	
Mass (g)	440	Mass (g)	250
Length (mm)	219	Effective length (mm)	165
Caliber (mm)	40	Diameter (mm)	10.3
Muzzle velocity (m/s)	1600	Density (g/cm^3)	17.5
Velocity decay (m/s/km)	120		

2. Purpose

As mentioned in Section 1.2, the CTA 40-mm gun system is a prime candidate for future medium caliber platforms (U.S. FSCS-UK TRACER) and possibly any revisions of existing systems, e.g., BFV. Therefore, the validation of the performance of the gun system is of major concern to many system developers. As part of the demonstration, the CTAI gun was mounted into an "old" BFV, from which the current 25-mm Bushmaster gun and feed system had been removed. (The 35-mm Bushmaster III had previously been mounted in the turret of this BFV for a similar demonstration in October 1998.) The primary ammunition being evaluated here is the APFSDS. To complete the evaluation of lethality at the target, an accurate impact velocity, which is determined by the muzzle velocity and velocity decay, is required. In addition, the pressures inside the vehicle and shock measurements on the vehicle were taken to estimate the effect of firing the CTWS from the BFV on the vehicle and on the crew. These experiments will give initial estimates of how the CTAI gun operates in the BFV and essential information about the APFSDS external characteristics.

3. Procedures

The gun and the BFV were located at the ATC facility Barricade 2. The gun was mounted onto the BFV. As mentioned earlier, CTAI was provided CAD drawings of the BFV's interior before the BFV arrived in the United States. CTAI developed their gun and feed system to fit in the BFV turret. It was installed in the turret, as can be seen in Figure 7.

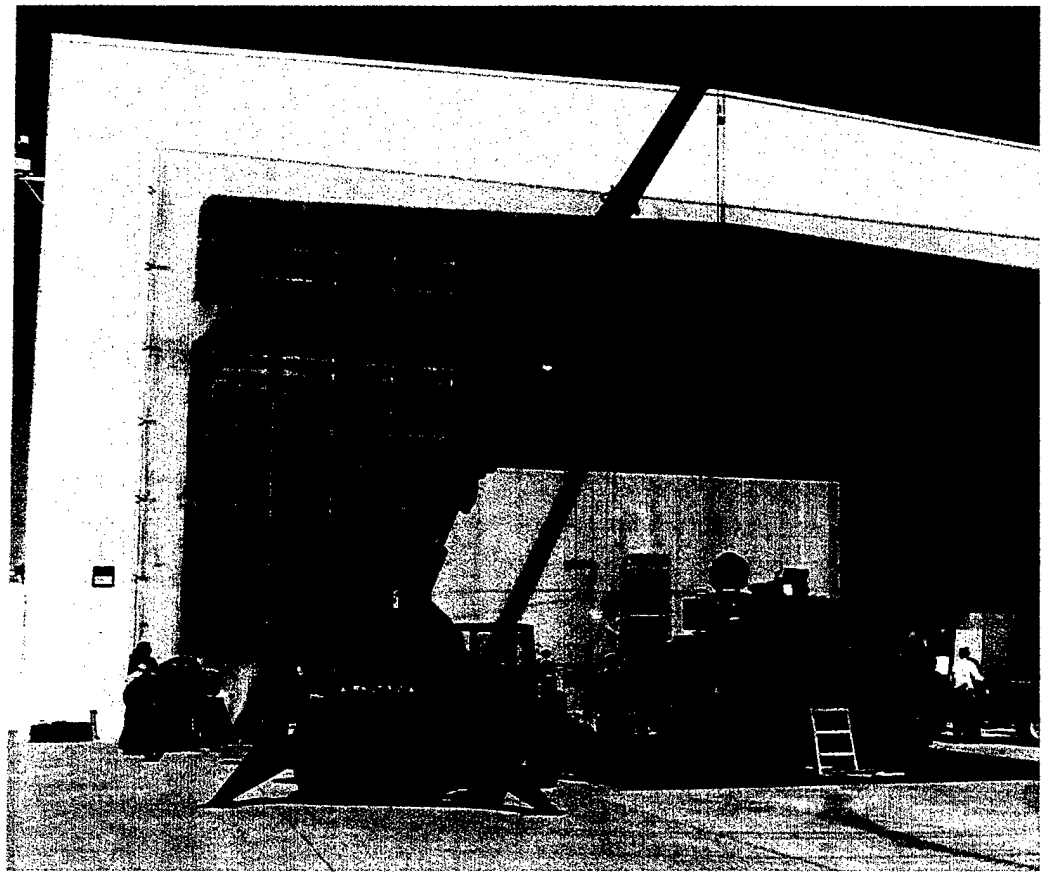

Figure 7. Mounting the CTWS in the BFV.

After the gun was mounted in the BFV turret, numerous practice shots with inert GP rounds (projectiles without high explosives) were fired. The functioning of the gun in the turret was evaluated during this phase. This was done in both single shot mode and in a three-round burst mode. Once it was evident that the gun was functioning properly, the APFSDS rounds were evaluated. These were fired to determine the actual muzzle velocity and velocity at range. The gun was elevated slightly so the velocity could be measured at a considerable range (i.e., farther than 4000 meters). While this was being done, the shock to the vehicle's exterior and the pressure inside the vehicle were measured.

A final series of shots was conducted to examine the yaw cycle at short distances, less than 100 meters. For this last portion, the gun was moved to the ATC facility Barricade 1, because of the better terrain environment.

4. Facility Setup

For all shots, the velocity was measured with a Weibel tracking system, which follows the projectile and determines velocity and deceleration as a function of time. This is converted to velocity at range. Also, high speed photography, located at various positions behind, to the side, and in front of the gun was used to observe the projectile exiting the gun barrel. Blast overpressures were measured inside the vehicle at several locations: in the crew compartment, in the turret, and in the driver area. Shock measurements were made at several locations on the exterior of the vehicle: the gun shield, turret roof, hull rear and hull front. ATC personnel reduced the data for the projectile velocity measurements, the blast overpressures, and the shock measurements (Walton, 2000).

5. Results and Discussion

The incorporation of the 40-mm CTAI gun system into the BFV vehicle was successful. With the assistance of the ATC personnel, the gun was easily installed in the turret, as previously seen in Figure 4. A photograph of the gun mounted in the BFV turret is shown in Figure 8. Figure 9 shows the 40-mm CTAI gun being fired from the BFV mount.

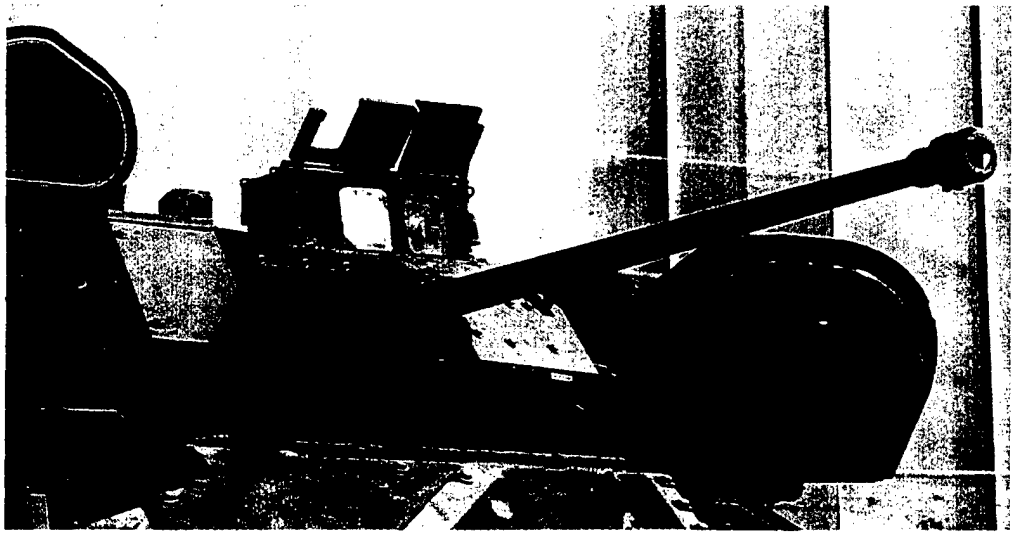

Figure 8. 40-mm CTAI Gun Mounted on the BFV.

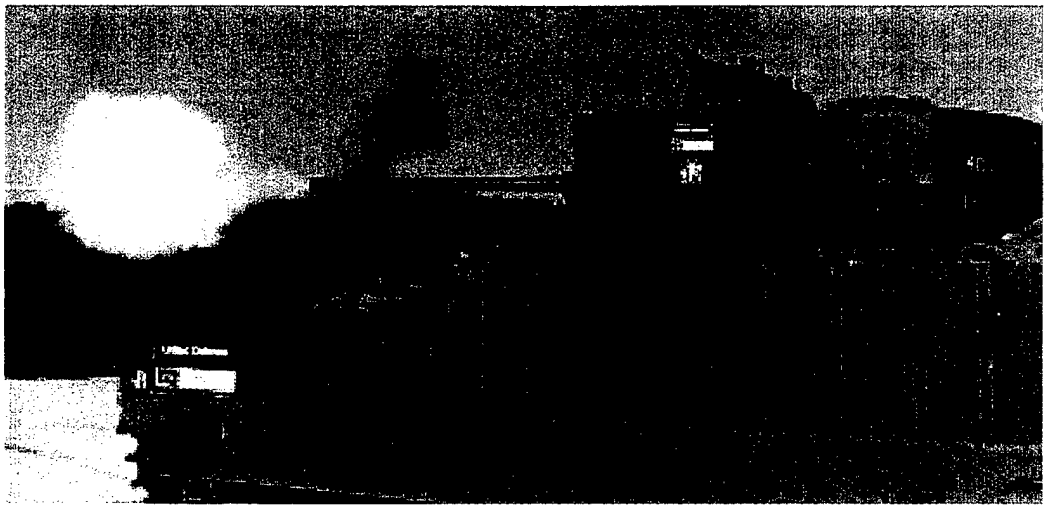

Figure 9. 40-mm CTAI Gun System Firing From the BFV.

The sequence of the rounds fired is shown in Table 2 which lists the shot number, the date, the type of round fired (GP - inert or APFSDS), and the shot mode (single shot or burst). Table 3 lists the meteorological conditions for the two days of the investigation.

Table 2

Schedule Results

Round Number	Date/Time	Round Type	Firing Mode
1	26 Oct / 16:40	GP - Inert	Single shot
2	26 Oct / 17:18	GP - Inert	Single shot
3	26 Oct / 17:57	GP - Inert	Single shot
4	27 Oct / 10:24	GP - Inert	Single shot
5	27 Oct / 11:08	APFSDS	Single shot
6	27 Oct / 11:43	APFSDS	Single shot
7	27 Oct / 12:18	APFSDS	Single shot
8	27 Oct / 14:32	APFSDS	Single shot, elevated
9	27 Oct / 14:41	APFSDS	Single shot, elevated
10	27 Oct / ~15:00	APFSDS	Single shot, elevated
11	27 Oct /15:43	GP - Inert	third burst
12	27 Oct / 16:04	GP - Inert	third burst

The high speed photography was used to capture the projectiles exiting the muzzle of the gun system. Figure 10 shows the GP round as it exits the muzzle and Figure 11 shows the APFSDS round. The sabot separation can be seen for the APFSDS round.

Table 3

Meteorological Conditions

Time	Wind Direction Average (°)	Wind Direction SD[a]	Wind Speed Average (m/s)	Wind Speed Peak (m/s)	Temp (°C)	Dew Point (°C)	Relative humidity (percent)	Pressure (Mbs)	Density (Kg/m^3)
				26 October 1999					
07:00	256	24	2.1	4.0	8.7	4.9	77	1019.5	1.2563
08:00	229	25	2.3	5.7	10.4	5.1	70	1019.5	1.2487
09:00	240	23	3.0	7.0	11.0	5.2	67	1019.9	1.2461
10:00	236	23	2.8	6.9	11.8	5.2	64	1019.6	1.2422
11:00	222	23	2.9	5.5	13.1	6.0	62	1019.0	1.2356
12:00	228	24	2.9	6.2	14.4	6.8	60	1017.9	1.2285
13:00	231	23	2.6	4.7	16.0	7.0	55	1016.7	1.2202
14:00	246	20	3.0	5.9	16.4	6.2	51	1015.9	1.2177
15:00	240	21	2.6	5.2	17.0	5.9	48	1015.2	1.2149
				27 October 1999					
07:00	339	10	1.9	3.2	9.2	2.1	61	1019.4	1.2543
08:00	340	14	1.7	3.2	10.4	2.3	57	1020.2	1.2499
09:00	348	15	2.8	6.0	12.7	2.0	48	1021.1	1.2414
10:00	351	14	3.8	6.7	13.4	1.7	45	1021.6	1.2386
11:00	1	19	3.5	6.7	14.6	2.8	45	1021.8	1.2334
12:00	4	20	3.5	7.1	15.3	2.5	42	1021.7	1.2304
13:00	10	21	3.4	7.3	15.6	2.4	41	1021.5	1.2289
14:00	358	27	3.1	6.4	15.3	3.1	44	1021.4	1.2299
15:00	7	21	3.3	7.0	15.5	3.3	44	1021.6	1.2292

[a]SD = standard deviation

Figure 10. Photograph of GP Projectile Exiting the Muzzle.

Figure 11. Photograph of APFSDS Projectile Exiting the Muzzle.

A sample of the velocity table is shown in Table 4. The velocity data tables for all the shots are listed in Appendix A. This sample table is for the APFSDS at extended range (~5000 meters).

The muzzle velocity achieved for this shot is 1639 m/s, which is more than advertised by CTAI (1600 m/s). Also shown in the table is the retardation or velocity decay (m/s/m). This retardation starts at 0.127 m/s/m and then drops to below 0.120 m/s/m at ranges greater than 500 meters. This initial high retardation is an indication of the yaw cycle that APFSDS rods experience when exiting the muzzle of the gun. As the penetrator begins its yaw cycle, it has a high yaw and a corresponding high drag (high velocity decay). As the yaw cycle dampens, reducing to nearly zero yaw, the penetrator will have much lower drag (low velocity decay). As can be seen in Table 4, after approximately 500 meters, the velocity decay is just below 0.120 m/s/m, which was the advertised value by CTAI.

The velocity of the inert GP round, although not the primary concern in this evaluation, was measured to be 1035 m/s. The velocity for these rounds was determined as far as approximately 700 meters. At this distance, the velocity had dropped to less than 700 m/s, for an average velocity decay of more than 0.400 m/s/m. For typical air-burst projectiles, the error in burst location greatly affects the projectile's performance. For air-burst projectiles with timed fuzes, the range error is reduced if the projectile is traveling at lower velocities. The large drag on the GP round may increase its probability of bursting at the correct location or may increase its probability of hit.

The data from the velocity measurements were plotted as a function of range for the GP (inert) round in Figure 12. Three of these shots (No. 1, No. 2, and No. 3) were measured from muzzle exit to 700 meters. The last shot (No. 4) was measured only to 400 meters. The fact that these curves lie very close to each other implies that the velocity and drag are very repeatable for these GP (inert) rounds.

Figure 13 shows the velocity as a function of range for the three shots of the APFSDS projectile at distances less than 1000 meters. These three plots show

Table 4

Sample Velocity Measurements

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	14:32:06.617	1-4	8

B2 CASSIDY 40-MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS

Velocity Results : Adjusted (based on sliding fits)

NO	TIME ms	VELOCITY m/s	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1639.096	0.00	-209.588	0.1279
1	61.248	1626.387	100.00	-205.418	0.1263
2	122.972	1613.837	200.00	-201.214	0.1247
3	185.176	1601.453	300.00	-196.979	0.1230
4	247.859	1589.304	400.00	-192.683	0.1212
5	311.020	1577.211	500.00	-189.885	0.1204
6	374.665	1565.279	600.00	-186.963	0.1194
7	438.796	1553.357	700.00	-184.844	0.1190
8	503.420	1541.471	800.00	-182.241	0.1182
9	568.543	1529.679	900.00	-180.140	0.1178
10	634.168	1517.942	1000.00	-177.947	0.1172
11	700.302	1506.254	1100.00	-176.168	0.1170
12	766.951	1494.582	1200.00	-174.677	0.1169
13	834.121	1482.904	1300.00	-173.472	0.1170
14	901.824	1471.196	1400.00	-172.540	0.1173
15	970.069	1459.424	1500.00	-170.984	0.1172
16	1038.866	1447.692	1600.00	-168.770	0.1166
17	1108.221	1436.094	1700.00	-166.392	0.1159
18	1178.134	1424.589	1800.00	-164.829	0.1157
19	1248.615	1413.057	1900.00	-163.350	0.1156
20	1319.676	1401.491	2000.00	-162.146	0.1157
21	1391.325	1389.889	2100.00	-161.352	0.1161
22	1463.575	1378.310	2200.00	-159.924	0.1160
23	1536.435	1366.685	2300.00	-159.153	0.1165
24	1609.919	1355.017	2400.00	-158.387	0.1169
25	1684.040	1343.315	2500.00	-157.179	0.1170
26	1758.810	1331.590	2600.00	-156.388	0.1174
27	1834.241	1319.844	2700.00	-155.610	0.1179
28	1910.349	1308.030	2800.00	-154.988	0.1185
29	1987.150	1296.123	2900.00	-154.290	0.1190
30	2064.660	1284.203	3000.00	-152.954	0.1191
31	2142.893	1272.291	3100.00	-151.473	0.1191
32	2221.861	1260.404	3200.00	-150.078	0.1191
33	2301.578	1248.491	3300.00	-148.724	0.1191
34	2382.058	1236.575	3400.00	-147.286	0.1191
35	2463.318	1224.665	3500.00	-145.891	0.1191
36	2545.373	1212.762	3600.00	-144.316	0.1190
37	2628.237	1200.860	3700.00	-142.965	0.1191
38	2711.925	1188.973	3800.00	-141.537	0.1190
39	2796.456	1177.061	3900.00	-139.973	0.1189
40	2881.845	1165.189	4000.00	-138.506	0.1189
41	2968.109	1153.317	4100.00	-137.008	0.1188
42	3055.264	1141.381	4200.00	-135.838	0.1190
43	3143.338	1129.486	4300.00	-134.094	0.1187
44	3232.340	1117.649	4400.00	-132.459	0.1185
45	3322.288	1105.875	4500.00	-130.748	0.1182
46	3413.203	1093.962	4600.00	-129.780	0.1186
47	3505.112	1082.132	4700.00	-128.416	0.1187
48	3598.034	1070.268	4800.00	-126.631	0.1183
49	3691.989	1058.456	4900.00	-124.910	0.1180

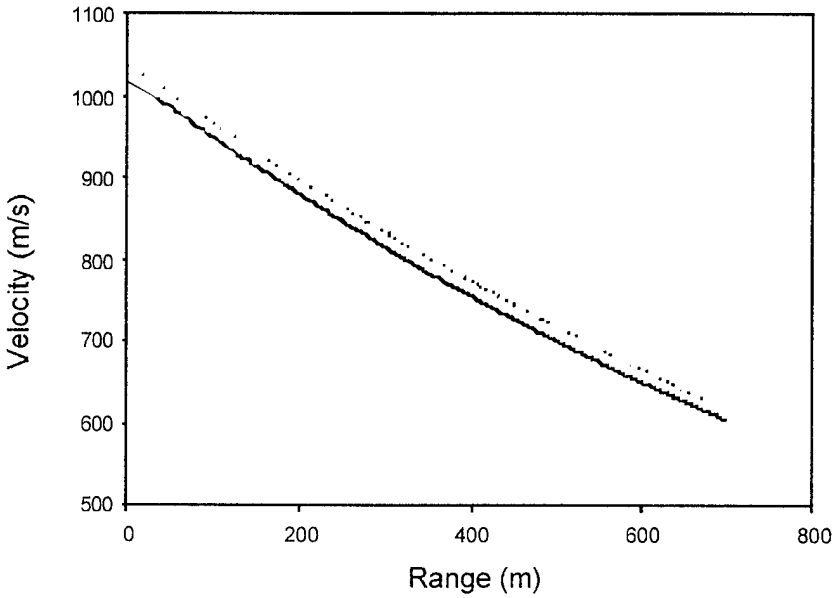

Figure 12. Velocity as a Function of Range for the GP Projectiles.

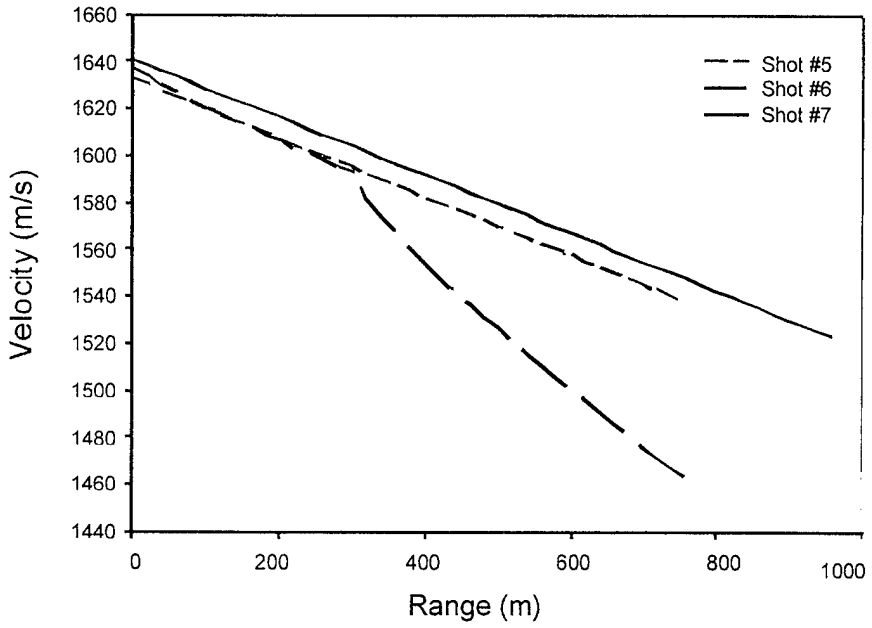

Figure 13. Velocity as a Function of Range for the APFSDS (short range).

approximately the same muzzle velocity (1630 to 1640 m/s) and velocity for about 300 meters. At 300 meters, Shot No. 6 begins to decelerate much faster than the other rounds. Shot No. 6 probably hit a yaw card pole, possibly causing it to lose some of its fins or inducing high yaw. This would definitely make it deviate from its flight line and decelerate much quicker. The velocity as a function of range for extended distances (~6000 meters) is shown in Figure 14, a plot of Shot No. 8 and 9. These extended distances were achieved by elevating the barrel slightly. As can be seen, the velocities of the two rounds track almost identically. The muzzle velocity is about 1640 m/s, and the average deceleration over 5000 meters is 0.12 m/s/m. This is a high muzzle velocity and very respectable velocity decay, which will give high velocity upon impact for typical target engagements, e.g., 1515 m/s at 1000 meters and 1400 m/s at 2000 meters. These high impact velocities at range should enhance terminal effects.

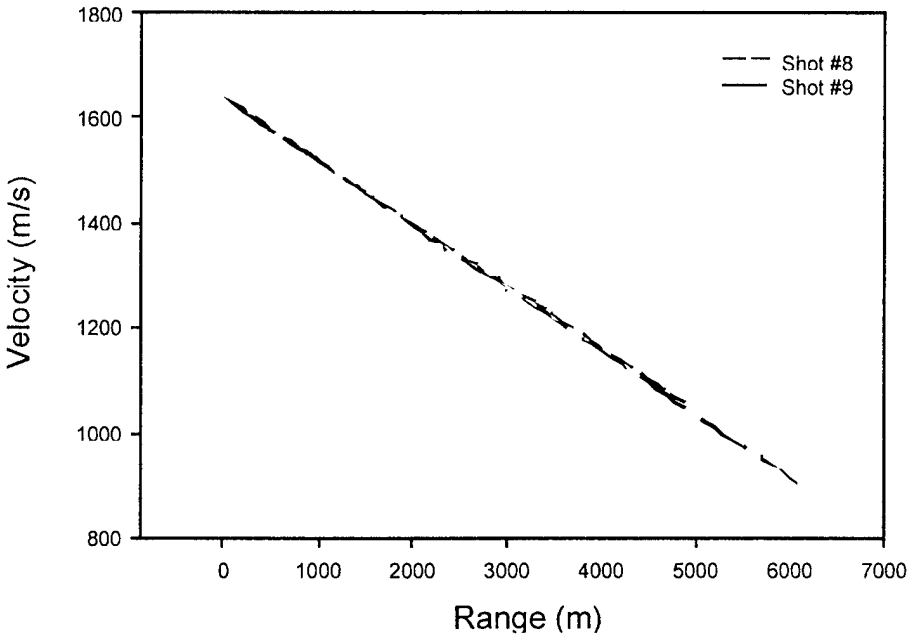

Figure 14. Velocity as a Function of Range for the APFSDS (extended range).

In addition to the velocity at range evaluation, some preliminary shots with the APFSDS projectiles were made with a downloaded propellant charge, to achieve a velocity of 1450 m/s. The yaw cycle and yaw node were determined for these downloaded projectiles. Numerous yaw cards, located from 60 to 100 meters, were used for the yaw cycle determination. For these velocities, the yaw was very repeatable, with a yaw node occurring at approximately 70 meters.

Blast overpressures were measured at four locations: the driver, the turret right, the turret left, and the rear crew compartment. These data were assessed by ATC in accordance with MIL-STD-1474C, Noise Limits for Military Materiel, and were compared to the A- and B-durations and maximum exposures per day for single hearing protection. Table 5 shows the peak pressures recorded and the maximum exposures per day for all the experiments at these locations. A sample plot of the time-pressure data is shown in Figure 15. All the plots of the overpressure for each location and each shot are listed in Appendix B.

Table 5

Measured Pressures and Maximum Allowable Exposures per Day

	Ch 1. Driver		Ch 2. Turret Left		Ch 3. Turret Right		Ch. 4 Rear Crew Area	
Rd No.	Peak Pressure (kPa)	Max. Exposure Per day	Peak Pressure (kPa)	Max. Exposure Per day	Peak Pressure (kPa)	Max. Exposure Per day	Peak Pressure (kPa)	Max. Exposure Per day
1	0.9	105631	2.4	2186	2.2	2930	1.3	13647*
2	1.0	64832	2.6	2092	2.2	2802	1.4	11748*
3	0.8	79216	2.8	1592	2.3	3714	1.2	17559*
4	1.0	74701	3.0	1195	2.3	3388	0.8	108578*
5	1.7	7812	2.9	1363	3.3	786	0.8	80724*
6	1.7	7710	3.3	837	3.4	676	1.1	23796*
7	1.7	7236	2.7	1648	3.5	632	0.9	53535*
8	1.4	10984	3.1	830	3.4	1339	1.0	39039*
9	1.6	10175	3.0	1122	3.5	1254	0.9	59874*
10	1.5	11777	3.0	874	3.4	1309	1.0	42837*
11	0.9	74880	3.2	2075	2.3	3591	0.9	60452*
12	1.1	35054	2.8	3376	2.2	3709	0.7	151655*

*Invalid data – a worst case of 200 ms B-duration used in maximum exposures per day calculation

The overpressures are summarized in Table 6, which shows the maximum pressure and corresponding smallest allowable exposures per day (as defined previously), recorded at each location for each firing scenario. The GP rounds had the lowest peak pressures for all locations. Going from a single shot to a burst with the GP rounds increases the peak pressure in most locations. The greatest peak overpressures were recorded for the single shot scenario with the APFSDS (not elevated) at the right turret location (directly behind the gun). The corresponding maximum allowable exposures per day would be 632, at this peak pressure. It is noted by ATC (Walton, 2000) that simply increasing the hearing protection level from the single ear protection to the double ear protection level causes the allowable exposures per day to increase by a factor of 20.

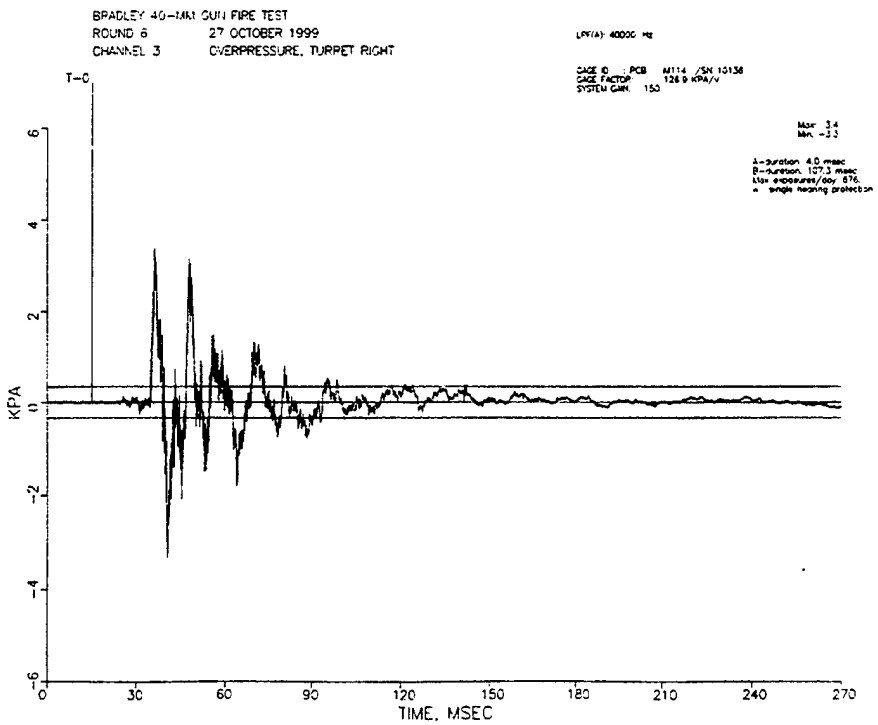

Figure 15. Sample Plot of Measured Overpressures at the Turret Right Location.

Table 6

Maximum Peak Pressures and Maximum Allowable Exposures per Day

	Ch 1. Driver		Ch 2. Turret Left		Ch 3. Turret Right		Ch. 4 Rear Crew Area	
Scenario	Peak Pressure (kPa)	Max, Exposure per day	Peak Pressure (kPa)	Max. Exposure per day	Peak Pressure (kPa)	Max. Exposure per day	Peak Pressure (kPa)	Max. Exposure per day
SS GP	1.0	64832	3.0	1195	2.2	2802	1.4	11748*
SS APFSDS	1.7	7236	3.3	837	3.5	632	1.1	23796*
SS APFSDS – Elevated	1.6	10175	3.1	830	3.5	1254	1.0	39039*
Burst GP	1.1	35054	3.2	2075	2.3	3591	0.9	60452*

*Invalid data – a worst case of 200 ms B-duration used in maximum exposures per day calculation

Accelerations were measured at four locations: the gun shield, the turret roof, the hull rear, and the hull front. Two transducers were used on the gun shield (one transverse and one vertical), three on the turret roof (one transverse, one vertical, and one longitudinal), three on the hull rear (one transverse, one vertical, and one longitudinal), and one vertical on the hull front. The sampling

rate was decreased from 200 Khz to 50 Khz after the first two shots. A sample shock response time plot, i.e., static acceleration as a function of natural frequency, for all shots recorded at the gun shield location is shown in Figure 16. All the plots for all the locations are shown in Appendix C. On all the plots, the upper and lower limits from the 1993 pliant structure ballistic shock specifications are shown. These limits were established in previous testing to show the effect of shock on a vehicle and its components (instrumentation, gauges, computers, etc.) (Walton 1994). The limits show the design criteria for the shock. The upper band is the maximum allowable and the lower band has a safety factor incorporated. The plots in Appendix C show that the gun shield location and the turret top were the worst case conditions for the maximum shock. Only one orientation for each of these locations was above the lower limit, and this was only slightly above the bottom band. The other locations were well below the bottom band, and therefore, all are well within design specifications. Based on these initial firings of the gun, no adverse effects on the BFV were determined.

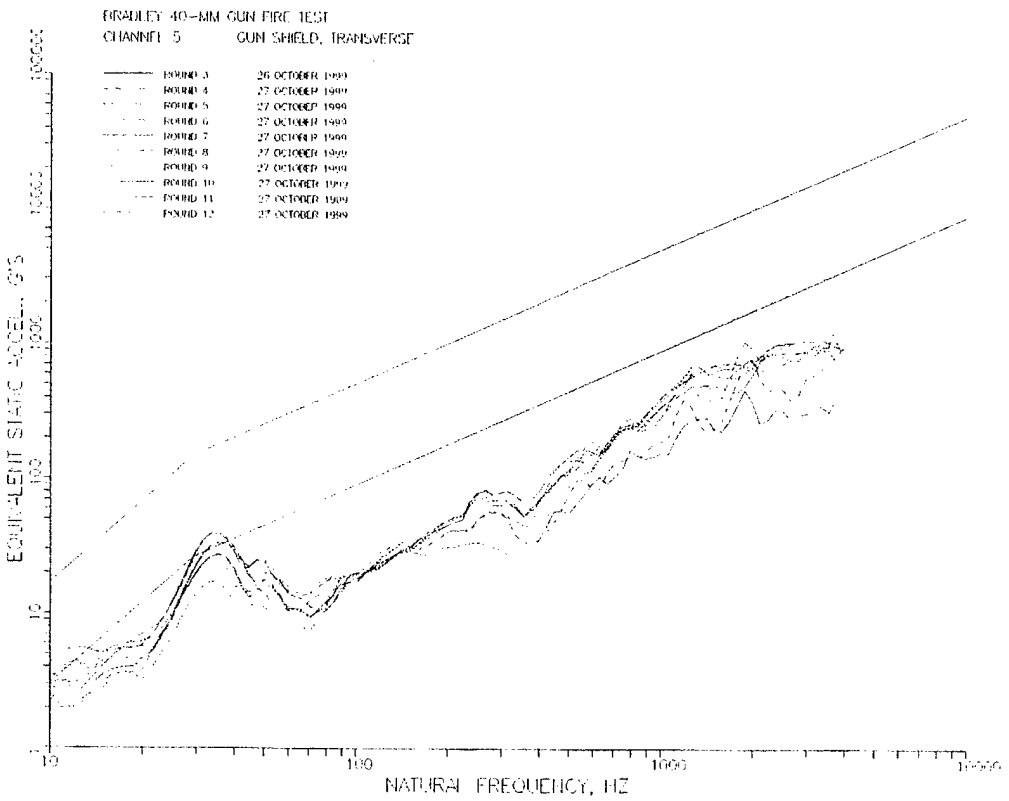

Figure 16. Sample Plot of the Measured Accelerations on the Gun Shield.

6. Summary

The evaluation of the 40-mm CTAI gun system was a great success. It allowed CTAI the opportunity to present their gun system on the BFV. The U.S. Government had the opportunity to evaluate the performance of the new gun system. This system was shown to fit into the BFV nicely.

The APFSDS ammunition performed as advertised, with a muzzle velocity of approximately 1640 m/s and a velocity decay of 0.12 m/s/m. These values will give the 40-mm CTAI APFSDS a high velocity at the target for typical engagement ranges. The measured shock to the vehicle and overpressures within the vehicle during firing all appear to be at acceptable levels for these initial experiments.

The program was a good cooperative endeavor and should be continued. It has increased the database for the U.S. Government and allows the contractors to demonstrate their ammunition in an unbiased format.

References

Walton, Scott, "Memorandum on the Bradley 40-mm Gun Firing Test," No. 00-BAB-01, Aberdeen Test Center, Aberdeen Proving Ground, MD, January 10, 2000.

Walton, W.S., and Bucci, J., "The Rationale for Shock Specifications and Shock Testing of Armored Ground Combat Vehicles," The Proceedings of the 65th Shock and Vibration Symposium, Vol 1, pp 285-293. San Diego CA, October 31-November 3,1994.

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APPENDIX A

INDIVIDUAL VELOCITY DATA

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Table A-1. Velocity Data for the GP Projectile, Shot No. 1

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991026	16:40:14.068	1-4	1

B2 CASSIDY 40 MM

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m	S/N dB	USED	
Muzz	0.000	1018.393	0.00	689.674	0.6772	36.1		254
1	24.998	1001.725	25.24	-693.057	0.6923	19.9	*	
2	28.429	998.893	28.67	-693.522	0.6944	22.4	*	
3	31.866	995.100	32.10	-693.987	0.6965	19.3	*	
4	35.296	993.470	35.52	-694.451	0.6987	21.9	*	
5	38.726	991.873	38.92	-694.915	0.7008	32.6	*	
6	42.157	988.747	42.32	-695.380	0.7030	39.3	*	
7	45.587	987.308	45.71	-695.844	0.7051	40.2	*	
8	49.018	984.127	49.09	-696.308	0.7073	44.4	*	
9	52.448	982.225	52.46	-696.773	0.7095	36.7	*	
10	55.885	980.832	55.83	-697.238	0.7117	23.2	*	
11	59.315	977.396	59.19	-697.702	0.7140	31.3	*	
12	62.746	974.929	62.54	-698.167	0.7162	31.9	*	
13	66.176	972.585	65.88	-696.178	0.7159	26.3	*	
14	69.606	970.780	69.21	-694.428	0.7159	20.3	*	
15	73.037	968.125	72.53	-695.462	0.7187	17.1	*	
16	76.474	965.059	75.85	-697.180	0.7223	16.1	*	
17	79.904	961.301	79.16	-696.680	0.7236	17.0	*	
18	83.334	959.683	82.46	-694.396	0.7231	24.7	*	
19	86.765	958.116	85.75	-694.365	0.7249	29.6	*	
20	90.195	955.352	89.03	-693.343	0.7256	34.4	*	
21	93.626	953.402	92.30	-690.688	0.7247	36.8	*	
22	97.056	950.629	95.57	-684.849	0.7203	45.2	*	
23	100.493	948.557	98.83	-678.445	0.7154	44.2	*	
24	103.923	946.298	102.08	-672.548	0.7109	47.2	*	
25	107.354	943.869	105.32	-669.154	0.7090	47.9	*	
26	110.784	941.686	108.56	-665.563	0.7069	45.4	*	
27	114.214	939.460	111.78	-657.909	0.7004	46.3	*	
28	117.645	936.959	115.00	-654.541	0.6984	47.1	*	
29	121.082	934.704	118.22	-655.320	0.7010	43.0	*	
30	124.512	932.572	121.42	-655.248	0.7026	40.1	*	
31	127.942	930.181	124.62	-653.127	0.7020	44.0	*	
32	131.373	928.003	127.81	-650.604	0.7010	38.4	*	
33	134.803	925.752	130.99	-648.485	0.7004	38.5	*	
34	138.234	923.603	134.16	-645.705	0.6990	34.2	*	
35	141.664	921.650	137.32	-643.211	0.6980	27.3	*	
36	145.101	920.665	140.49	-640.464	0.6967	17.1	*	
37	148.531	916.894	143.64	-638.038	0.6957	34.4	*	
38	151.962	914.715	146.78	-635.414	0.6945	37.0	*	

39	155.392	912.481	149.91	-632.547	0.6931	39.1	*
40	158.822	910.388	153.04	-629.854	0.6917	42.6	*
41	162.253	908.239	156.16	-627.531	0.6908	42.3	*
42	165.683	906.081	159.27	-625.061	0.6898	44.4	*
43	169.120	904.009	162.38	-623.188	0.6893	41.5	*
44	172.550	901.856	165.48	-620.871	0.6884	43.1	*
45	175.981	899.728	168.57	-618.550	0.6875	45.6	*
46	179.411	897.626	171.65	-616.021	0.6863	43.5	*
47	182.842	895.622	174.73	-612.914	0.6844	44.1	*
48	186.272	893.537	177.80	-608.018	0.6805	43.0	*
49	189.709	891.439	180.87	-602.102	0.6754	47.2	*
50	193.139	889.379	183.92	-599.402	0.6740	43.5	*
51	196.570	887.332	186.97	-596.892	0.6727	44.3	*
52	200.000	885.285	190.01	-594.290	0.6713	45.1	*
53	203.430	883.217	193.04	-591.657	0.6699	48.6	*
54	206.861	881.217	196.07	-589.087	0.6685	47.9	*
55	210.291	879.191	199.09	-586.512	0.6671	47.1	*
56	213.728	877.157	202.10	-583.950	0.6657	48.4	*
57	217.158	875.166	205.11	-581.411	0.6643	47.2	*
58	220.589	873.170	208.11	-578.952	0.6630	47.7	*
59	224.019	871.208	211.10	-576.482	0.6617	46.2	*
60	227.450	869.241	214.09	-573.785	0.6601	46.5	*
61	230.880	867.305	217.06	-571.246	0.6587	48.8	*
62	234.317	865.330	220.04	-568.752	0.6573	46.7	*
63	237.747	863.372	223.01	-566.177	0.6558	49.3	*
64	241.178	861.423	225.97	-563.568	0.6542	50.1	*
65	244.608	859.529	228.92	-561.145	0.6529	47.3	*
66	248.038	857.623	231.86	-558.677	0.6515	45.6	*
67	251.469	855.690	234.80	-556.136	0.6499	48.2	*
68	254.899	853.745	237.73	-553.828	0.6487	45.3	*
69	258.336	851.885	240.66	-551.464	0.6474	46.3	*
70	261.766	849.983	243.58	-549.109	0.6460	46.3	*
71	265.197	848.106	246.50	-546.774	0.6447	45.6	*
72	268.627	846.263	249.40	-544.479	0.6434	48.3	*
73	272.058	844.390	252.30	-542.245	0.6422	47.4	*
74	275.488	842.470	255.19	-539.798	0.6407	46.5	*
75	278.919	840.670	258.08	-537.265	0.6391	43.9	*
76	282.355	838.886	260.97	-534.900	0.6377	45.2	*
77	285.786	836.962	263.84	-532.396	0.6361	45.2	*
78	289.216	835.208	266.71	-530.506	0.6352	48.4	*
79	292.647	833.378	269.57	-529.993	0.6359	43.4	*
80	296.077	831.548	272.43	-530.169	0.6375	42.5	*
81	299.507	829.739	275.28	-528.737	0.6372	47.8	*
82	302.944	827.989	278.13	-527.197	0.6367	44.8	*
83	306.374	826.193	280.96	-525.806	0.6364	45.3	*
84	309.805	824.392	283.80	-524.150	0.6358	45.4	*
85	313.235	822.575	286.62	-522.044	0.6347	45.5	*
86	316.666	820.893	289.44	-519.880	0.6334	43.4	*
87	320.096	819.169	292.25	-517.816	0.6323	42.4	*
88	323.526	817.432	295.06	-515.525	0.6309	41.2	*
89	326.963	815.686	297.86	-512.908	0.6290	43.0	*
90	330.394	814.018	300.66	-510.999	0.6281	38.5	*
91	333.824	811.512	303.45	-508.594	0.6265	29.1	*
92	337.254	809.164	306.23	-506.081	0.6247	32.2	*
93	340.685	808.397	309.00	-503.451	0.6228	37.5	*
94	344.115	806.458	311.77	-500.613	0.6206	42.0	*
95	347.552	804.603	314.54	-497.631	0.6182	41.3	*
96	350.982	803.227	317.30	-494.550	0.6157	39.8	*

97	354.413	801.630	320.05	-491.448	0.6131	35.3	*
98	357.843	800.203	322.80	-488.702	0.6110	33.9	*
99	361.274	798.339	325.54	-484.985	0.6076	34.7	*
100	364.704	796.636	328.28	-481.131	0.6040	35.8	*
101	368.134	795.077	331.01	-477.330	0.6005	36.1	*
102	371.571	793.249	333.74	-473.451	0.5968	35.0	*
103	375.002	791.875	336.45	-470.639	0.5944	35.0	*
104	378.432	789.998	339.17	-469.628	0.5944	34.8	*
105	381.862	788.440	341.87	-469.246	0.5951	36.0	*
106	385.293	786.835	344.58	-467.683	0.5943	36.2	*
107	388.723	785.225	347.27	-466.971	0.5947	33.7	*
108	392.160	783.667	349.97	-465.426	0.5939	34.0	*
109	395.590	782.104	352.66	-463.515	0.5927	36.8	*
110	399.021	780.392	355.34	-461.109	0.5908	36.9	*
111	402.451	778.970	358.01	-458.790	0.5890	37.4	*
112	405.882	777.364	360.68	-456.894	0.5878	39.6	*
113	409.312	775.848	363.34	-455.196	0.5868	38.7	*
114	412.742	774.235	366.00	-453.183	0.5853	43.4	*
115	416.179	772.714	368.66	-450.692	0.5833	41.3	*
116	419.610	771.126	371.31	-448.931	0.5822	38.9	*
117	423.040	769.720	373.95	-446.973	0.5808	36.2	*
118	426.470	767.979	376.59	-444.945	0.5793	38.1	*
119	429.901	766.493	379.22	-443.178	0.5782	40.0	*
120	433.331	765.009	381.85	-441.418	0.5770	40.4	*
121	436.762	763.512	384.47	-439.611	0.5758	40.3	*
122	440.198	762.047	387.09	-438.055	0.5749	41.2	*
123	443.629	760.480	389.70	-436.038	0.5734	39.2	*
124	447.059	758.968	392.31	-434.105	0.5719	40.8	*
125	450.490	757.416	394.91	-432.106	0.5704	38.5	*
126	453.920	756.048	397.51	-430.287	0.5691	39.6	*
127	457.350	754.577	400.10	-428.560	0.5679	36.5	*
128	460.787	753.146	402.69	-426.610	0.5665	35.8	*
129	464.218	751.657	405.27	-425.031	0.5655	37.5	*
130	467.648	750.385	407.84	-422.705	0.5635	37.2	*
131	471.078	748.744	410.42	-421.130	0.5624	39.1	*
132	474.509	747.294	412.98	-419.381	0.5612	38.3	*
133	477.939	745.845	415.54	-417.596	0.5599	38.8	*
134	481.370	744.436	418.10	-415.796	0.5585	38.9	*
135	484.807	743.077	420.65	-414.117	0.5573	36.4	*
136	488.237	741.616	423.20	-412.841	0.5567	40.8	*
137	491.667	740.197	425.74	-411.329	0.5557	43.3	*
138	495.098	738.766	428.28	-410.063	0.5551	43.7	*
139	498.528	737.271	430.81	-408.540	0.5540	44.3	*
140	501.959	736.040	433.34	-406.972	0.5530	39.6	*
141	505.395	734.490	435.87	-405.434	0.5519	40.7	*
142	508.826	733.288	438.38	-403.598	0.5505	37.9	*
143	512.256	731.861	440.90	-401.807	0.5490	39.6	*
144	515.686	730.426	443.40	-400.422	0.5482	38.7	*
145	519.117	729.169	445.91	-399.051	0.5473	39.0	*
146	522.547	727.729	448.41	-397.560	0.5463	37.0	*
147	525.978	726.393	450.90	-395.961	0.5451	36.7	*
148	529.415	724.863	453.39	-394.366	0.5440	38.4	*
149	532.845	723.661	455.88	-392.743	0.5427	35.0	*
150	536.275	722.323	458.36	-391.224	0.5416	36.7	*
151	539.706	720.990	460.83	-389.959	0.5409	35.5	*
152	543.136	719.631	463.31	-388.601	0.5400	36.6	*
153	546.566	718.257	465.77	-387.092	0.5389	38.6	*
154	549.997	716.981	468.23	-385.910	0.5383	36.2	*

155	553.434	715.647	470.70	-384.296	0.5370	37.4	*
156	556.864	714.290	473.15	-382.883	0.5360	36.2	*
157	560.294	712.982	475.60	-381.378	0.5349	35.2	*
158	563.725	711.736	478.04	-379.932	0.5338	36.0	*
159	567.155	710.441	480.48	-378.498	0.5328	36.8	*
160	570.586	709.078	482.91	-377.134	0.5318	36.8	*
161	574.022	707.867	485.35	-376.148	0.5314	35.5	*
162	577.453	706.619	487.77	-374.833	0.5305	31.9	*
163	580.883	705.215	490.20	-373.506	0.5296	32.0	*
164	584.314	704.037	492.61	-372.183	0.5287	33.2	*
165	587.744	702.691	495.03	-370.971	0.5279	33.9	*
166	591.175	701.446	497.43	-369.750	0.5271	32.4	*
167	594.605	700.160	499.84	-368.399	0.5262	32.5	*
168	598.042	698.949	502.24	-367.076	0.5252	34.1	*
169	601.472	697.667	504.64	-366.039	0.5247	34.5	*
170	604.902	696.346	507.03	-364.632	0.5236	34.8	*
171	608.333	695.153	509.42	-363.230	0.5225	34.2	*
172	611.763	693.909	511.80	-361.956	0.5216	33.6	*
173	615.194	692.660	514.18	-360.595	0.5206	33.8	*
174	618.631	691.420	516.56	-359.091	0.5194	33.3	*
175	622.061	690.120	518.92	-357.597	0.5181	33.5	*
176	625.491	688.946	521.29	-356.335	0.5172	33.7	*
177	628.922	687.766	523.65	-354.711	0.5158	32.6	*
178	632.352	686.502	526.01	-353.214	0.5145	31.1	*
179	635.783	685.345	528.36	-351.808	0.5134	32.7	*
180	639.213	684.154	530.71	-350.252	0.5120	33.4	*
181	642.650	682.850	533.06	-348.711	0.5106	36.0	*
182	646.080	681.806	535.40	-347.415	0.5096	34.4	*
183	649.510	680.540	537.74	-346.252	0.5088	33.7	*
184	652.941	679.370	540.07	-344.894	0.5077	36.9	*
185	656.371	678.183	542.40	-343.269	0.5062	36.0	*
186	659.802	676.960	544.72	-342.003	0.5052	35.8	*
187	663.238	675.839	547.05	-340.836	0.5043	34.4	*
188	666.669	674.614	549.36	-339.619	0.5034	36.4	*
189	670.099	673.580	551.68	-338.427	0.5025	34.9	*
190	673.530	672.348	553.98	-337.290	0.5017	35.9	*
191	676.960	671.216	556.29	-335.983	0.5006	34.0	*
192	680.391	670.027	558.59	-334.600	0.4994	33.1	*
193	683.821	668.921	560.89	-333.347	0.4984	35.6	*
194	687.258	667.736	563.18	-331.815	0.4969	35.4	*
195	690.688	666.543	565.47	-330.426	0.4957	35.6	*
196	694.119	665.464	567.76	-329.029	0.4944	33.9	*
197	697.549	664.394	570.04	-327.653	0.4932	33.7	*
198	700.979	663.235	572.31	-326.333	0.4920	36.1	*
199	704.410	662.058	574.59	-324.994	0.4909	36.5	*
200	707.840	661.056	576.86	-323.556	0.4895	34.0	*
201	711.277	659.880	579.13	-321.900	0.4878	36.9	*
202	714.707	658.682	581.39	-320.504	0.4865	34.4	*
203	718.138	657.714	583.65	-319.084	0.4852	38.4	*
204	721.568	656.604	585.90	-317.708	0.4839	37.1	*
205	724.999	655.506	588.15	-316.314	0.4825	36.6	*
206	728.429	654.499	590.40	-314.938	0.4812	38.2	*
207	731.866	653.317	592.64	-313.493	0.4798	37.5	*
208	735.296	652.293	594.88	-312.364	0.4789	34.2	*
209	738.727	651.200	597.12	-310.850	0.4773	35.4	*
210	742.157	650.129	599.35	-309.567	0.4761	34.8	*
211	745.587	649.093	601.58	-308.450	0.4752	36.8	*
212	749.018	648.042	603.81	-307.136	0.4739	36.5	*

213	752.448	647.055	606.03	-305.968	0.4729	38.0	*
214	755.885	646.002	608.25	-305.136	0.4724	36.7	*
215	759.315	644.834	610.46	-304.290	0.4718	35.7	*
216	762.746	643.806	612.67	-303.275	0.4710	35.6	*
217	766.176	642.825	614.88	-302.108	0.4700	36.2	*
218	769.606	641.730	617.08	-300.982	0.4690	35.3	*
219	773.037	640.850	619.28	-300.203	0.4685	34.1	*
220	776.474	639.712	621.48	-299.367	0.4680	35.4	*
221	779.904	638.710	623.68	-298.577	0.4675	35.5	*
222	783.335	637.750	625.87	-297.858	0.4671	31.4	*
223	786.765	636.650	628.05	-297.040	0.4666	32.0	*
224	790.195	635.682	630.23	-296.343	0.4662	30.7	*
225	793.626	634.663	632.41	-295.181	0.4651	33.0	*
226	797.056	633.555	634.59	-294.556	0.4649	31.1	*
227	800.493	632.616	636.76	-294.163	0.4650	30.6	*
228	803.923	631.584	638.93	-293.748	0.4651	31.3	*
229	807.354	630.731	641.10	-293.098	0.4648	29.9	*
230	810.784	629.590	643.26	-292.112	0.4640	30.4	*
231	814.215	628.582	645.42	-290.855	0.4627	30.0	*
232	817.645	627.571	647.57	-289.252	0.4609	29.3	*
233	821.075	626.616	649.72	-287.727	0.4592	27.7	*
234	824.512	625.584	651.87	-286.826	0.4585	26.5	*
235	827.943	624.675	654.02	-285.331	0.4568	28.3	*
236	831.373	623.603	656.16	-283.895	0.4552	28.3	*
237	834.803	622.768	658.30	-282.993	0.4545	25.3	*
238	838.234	621.658	660.43	-282.190	0.4539	27.1	*
239	841.664	620.456	662.56	-281.803	0.4540	25.1	*
240	845.101	619.664	664.69	-281.114	0.4536	25.2	*
241	848.531	618.672	666.82	-281.041	0.4541	20.7	*
242	851.962	617.893	668.94	-280.997	0.4548	20.2	*
243	855.392	617.058	671.06	-281.297	0.4559	19.9	*
244	858.822	616.103	673.17	-281.506	0.4570	18.0	*
245	862.253	615.451	675.28	-281.715	0.4581	15.8	*
246	865.683	614.126	677.39	-281.923	0.4591	17.3	*
247	869.120	612.827	679.50	-282.132	0.4602	19.6	*
248	872.551	612.695	681.60	-282.341	0.4612	15.2	*
249	875.981	611.085	683.70	-282.550	0.4623	14.6	*
250	879.411	610.270	685.80	-282.759	0.4634	15.0	*
251	882.842	609.166	687.89	-282.968	0.4645	16.4	*
252	886.272	608.338	689.98	-283.176	0.4656	12.6	*
253	889.709	607.200	692.06	-283.385	0.4667	12.6	*
254	893.139	606.261	694.15	-283.594	0.4677	1.8	
255	896.570	605.277	696.22	-283.803	0.4688	-1.0	
256	900.000	604.142	698.30	-284.011	0.4699	7.1	*

Table A-2. Velocity Data for the GP Projectile, Shot No. 2

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991026	17:17:53.403	1-4	2

B2 CASSIDY 40 MM

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1036.216	0.00	-715.562	0.6906
1	19.431	1022.316	20.00	-715.235	0.6996
2	39.130	1008.233	40.00	-714.902	0.7091
3	59.108	993.960	60.00	-714.562	0.7189
4	79.378	979.487	80.00	-714.217	0.7292
5	99.953	964.662	100.00	-699.103	0.7247
6	120.840	950.441	120.00	-673.593	0.7087
7	142.040	936.433	140.00	-653.721	0.6981
8	163.557	922.567	160.00	-638.622	0.6922
9	185.399	908.858	180.00	-617.963	0.6799
10	207.570	895.380	200.00	-599.506	0.6696
11	230.075	882.122	220.00	-581.472	0.6592
12	252.917	869.083	240.00	-563.280	0.6481
13	276.102	856.273	260.00	-546.838	0.6386
14	299.631	843.669	280.00	-543.410	0.6441
15	323.523	830.679	300.00	-524.586	0.6315
16	347.784	818.276	320.00	-495.563	0.6056
17	372.399	806.787	340.00	-469.066	0.5814
18	397.371	795.080	360.00	-463.816	0.5834
19	422.712	783.482	380.00	-451.504	0.5763
20	448.427	772.099	400.00	-438.590	0.5681
21	474.520	760.905	420.00	-425.463	0.5592
22	500.998	749.844	440.00	-415.349	0.5539
23	527.867	738.858	460.00	-407.147	0.5511
24	555.139	727.936	480.00	-397.567	0.5462
25	582.820	717.159	500.00	-387.712	0.5406
26	610.918	706.465	520.00	-379.202	0.5368
27	639.443	695.844	540.00	-369.734	0.5314
28	668.404	685.372	560.00	-359.087	0.5239
29	697.808	675.045	580.00	-348.372	0.5161
30	727.660	664.934	600.00	-337.224	0.5072
31	757.967	654.959	620.00	-327.848	0.5006
32	788.736	645.101	640.00	-316.615	0.4908
33	819.971	635.630	660.00	-312.129	0.4911
34	851.683	625.380	680.00	-351.360	0.5618
35	883.964	613.502	700.00	-391.797	0.6386

Table A-3. Velocity Data for the GP Projectile, Shot No. 3

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991026	17:57:13.913	1-4	3

B2 CASSIDY 40 MM

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1032.809	0.00	-745.864	0.7222
1	19.502	1018.326	20.00	-739.430	0.7261
2	39.283	1003.763	40.00	-732.903	0.7302
3	59.355	989.120	60.00	-726.281	0.7343
4	79.727	974.392	80.00	-719.559	0.7385
5	100.413	959.395	100.00	-702.310	0.7320
6	121.419	944.972	120.00	-675.784	0.7151
7	142.743	930.927	140.00	-654.020	0.7026
8	164.389	916.999	160.00	-637.195	0.6949
9	186.367	903.107	180.00	-617.995	0.6843
10	208.680	889.637	200.00	-595.991	0.6699
11	231.330	876.392	220.00	-577.431	0.6589
12	254.323	863.310	240.00	-560.672	0.6495
13	277.665	850.424	260.00	-543.152	0.6387
14	301.360	837.817	280.00	-529.025	0.6314
15	325.413	825.212	300.00	-514.741	0.6238
16	349.834	812.793	320.00	-498.415	0.6132
17	374.626	800.686	340.00	-481.303	0.6011
18	399.790	788.854	360.00	-465.044	0.5895
19	425.334	777.151	380.00	-451.853	0.5814
20	451.262	765.617	400.00	-438.574	0.5728
21	477.581	754.254	420.00	-422.703	0.5604
22	504.295	743.184	440.00	-407.467	0.5483
23	531.404	732.355	460.00	-395.634	0.5402
24	558.917	721.593	480.00	-387.287	0.5367
25	586.842	710.885	500.00	-377.626	0.5312
26	615.188	700.337	520.00	-364.293	0.5202
27	643.957	690.093	540.00	-350.893	0.5085
28	673.152	680.016	560.00	-341.437	0.5021
29	702.783	670.013	580.00	-332.693	0.4966
30	732.855	660.162	600.00	-323.146	0.4895
31	763.376	650.443	620.00	-313.866	0.4825
32	794.354	640.865	640.00	-303.268	0.4732
33	825.792	631.517	660.00	-291.326	0.4613
34	857.693	622.401	680.00	-284.358	0.4569
35	890.064	613.291	700.00	-278.691	0.4544

Table A-4. Velocity Data for the GP Projectile, Shot No. 4

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	10:23:56.336	1-4	4

B2 CASSIDY 40 GPI

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1030.597	0.00	-652.350	0.6330
1	19.528	1017.669	20.00	-671.666	0.6600
2	39.311	1004.188	40.00	-691.233	0.6884
3	59.367	990.125	60.00	-711.070	0.7182
4	79.719	975.258	80.00	-724.872	0.7433
5	100.388	960.175	100.00	-708.793	0.7382
6	121.376	945.702	120.00	-686.454	0.7259
7	142.688	931.291	140.00	-665.383	0.7145
8	164.329	917.064	160.00	-645.290	0.7037
9	186.307	903.085	180.00	-621.915	0.6887
10	208.621	889.561	200.00	-597.526	0.6717
11	231.274	876.284	220.00	-576.229	0.6576
12	254.269	863.283	240.00	-556.778	0.6450
13	277.610	850.505	260.00	-540.164	0.6351
14	301.301	837.918	280.00	-528.716	0.6310
15	325.351	825.275	300.00	-518.983	0.6289
16	349.773	812.700	320.00	-502.512	0.6183
17	374.568	800.590	340.00	-481.702	0.6017
18	399.738	788.680	360.00	-467.046	0.5922
19	425.288	776.940	380.00	-452.898	0.5829
20	451.223	765.372	400.00	-439.603	0.5744
21	477.552	753.945	420.00	-427.818	0.5674
22	504.279	742.684	440.00	-414.627	0.5583
23	531.412	731.615	460.00	-401.312	0.5485
24	558.955	720.744	480.00	-388.713	0.5393
25	586.913	710.068	500.00	-373.351	0.5258
26	615.288	699.711	520.00	-358.725	0.5127
27	644.080	689.571	540.00	-346.693	0.5028
28	673.295	679.629	560.00	-334.965	0.4929
29	702.937	669.856	580.00	-324.366	0.4842
30	733.009	660.302	600.00	-315.207	0.4774
31	763.521	650.728	620.00	-308.242	0.4737
32	794.480	641.408	640.00	-298.675	0.4657
33	825.888	632.050	660.00	-306.328	0.4847
34	857.780	622.105	680.00	-317.383	0.5102
35	890.201	611.635	700.00	-328.618	0.5373

Table A-5. Velocity Data for the APFSDS Projectile, Shot No. 5

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	11:08:54.955	1-4	5

B2 CASSIDY 40MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1632.074	0.00	-204.519	0.1253
1	12.264	1629.568	20.00	-204.111	0.1253
2	24.546	1627.063	40.00	-203.701	0.1252
3	36.848	1624.560	60.00	-203.291	0.1251
4	49.169	1622.058	80.00	-202.881	0.1251
5	61.508	1619.557	100.00	-202.469	0.1250
6	73.867	1617.058	120.00	-202.057	0.1250
7	86.244	1614.560	140.00	-201.645	0.1249
8	98.641	1612.063	160.00	-201.231	0.1248
9	111.057	1609.567	180.00	-200.818	0.1248
10	123.493	1607.073	200.00	-200.403	0.1247
11	135.947	1604.580	220.00	-199.988	0.1246
12	148.421	1602.088	240.00	-199.572	0.1246
13	160.915	1599.598	260.00	-199.156	0.1245
14	173.427	1597.109	280.00	-198.738	0.1244
15	185.960	1594.621	300.00	-198.321	0.1244
16	198.512	1592.135	320.00	-197.902	0.1243
17	211.083	1589.650	340.00	-197.483	0.1242
18	223.674	1587.167	360.00	-197.063	0.1242
19	236.286	1584.685	380.00	-196.643	0.1241
20	248.916	1582.205	400.00	-196.222	0.1240
21	261.567	1579.726	420.00	-195.800	0.1240
22	274.237	1577.248	440.00	-195.378	0.1239
23	286.928	1574.773	460.00	-194.955	0.1238
24	299.638	1572.298	480.00	-194.531	0.1237
25	312.368	1569.825	500.00	-194.106	0.1237
26	325.118	1567.354	520.00	-193.681	0.1236
27	337.889	1564.884	540.00	-193.256	0.1235
28	350.679	1562.416	560.00	-192.829	0.1234
29	363.490	1559.949	580.00	-192.402	0.1233
30	376.321	1557.484	600.00	-191.974	0.1233
31	389.173	1555.021	620.00	-191.546	0.1232
32	402.044	1552.560	640.00	-191.116	0.1231
33	414.937	1550.100	660.00	-190.687	0.1230
34	427.849	1547.641	680.00	-190.256	0.1229
35	440.782	1545.185	700.00	-189.825	0.1229
36	453.736	1542.730	720.00	-189.393	0.1228
37	466.710	1540.277	740.00	-188.960	0.1227
38	479.705	1537.825	760.00	-188.523	0.1226

Table A-6. Velocity Data for the APFSDS Projectile, Shot No. 6

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	11:43:07.297	1-4	6

B2 CASSIDY 40MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1637.300	0.00	-293.364	0.1792
1	12.229	1633.761	20.00	-285.552	0.1748
2	24.483	1630.309	40.00	-277.723	0.1704
3	36.764	1626.947	60.00	-269.878	0.1659
4	49.069	1623.675	80.00	-262.016	0.1614
5	61.399	1620.493	100.00	-254.139	0.1568
6	73.753	1617.403	120.00	-246.247	0.1523
7	86.130	1614.404	140.00	-238.340	0.1476
8	98.529	1611.498	160.00	-230.418	0.1430
9	110.951	1608.696	180.00	-223.101	0.1387
10	123.394	1605.989	200.00	-214.928	0.1338
11	135.858	1603.349	220.00	-209.328	0.1306
12	148.342	1600.763	240.00	-205.021	0.1281
13	160.846	1598.227	260.00	-200.708	0.1256
14	173.369	1595.742	280.00	-196.387	0.1231
15	185.912	1593.307	300.00	-192.060	0.1205
16	198.517	1581.389	320.00	-585.361	0.3702
17	211.194	1574.116	340.00	-562.348	0.3573
18	223.928	1567.103	360.00	-539.230	0.3441
19	236.718	1560.356	380.00	-516.010	0.3307
20	249.562	1553.879	400.00	-492.692	0.3171
21	262.459	1547.677	420.00	-469.278	0.3032
22	275.406	1541.946	440.00	-450.104	0.2919
23	288.400	1536.422	460.00	-426.387	0.2775
24	301.440	1531.159	480.00	-405.586	0.2649
25	314.524	1525.951	500.00	-400.384	0.2624
26	327.654	1520.677	520.00	-394.079	0.2592
27	340.829	1515.479	540.00	-388.001	0.2560
28	354.047	1510.440	560.00	-381.295	0.2524
29	367.310	1505.484	580.00	-374.754	0.2489
30	380.617	1500.543	600.00	-372.138	0.2480
31	393.968	1495.570	620.00	-369.413	0.2470
32	407.363	1490.699	640.00	-364.804	0.2447
33	420.801	1485.821	660.00	-362.882	0.2442
34	434.284	1480.932	680.00	-359.267	0.2426
35	447.811	1476.094	700.00	-356.331	0.2414
36	461.383	1471.280	720.00	-353.382	0.2402
37	474.998	1466.491	740.00	-350.421	0.2390
38	488.659	1461.727	760.00	-347.450	0.2377

Table A-7. Velocity Data for the APFSDS Projectile, Shot No. 7

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	12:17:59.681	1-4	7

B2 CASSIDY 40MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted
(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1640.004	0.00	-188.284	0.1148
1	12.204	1637.701	20.00	-189.116	0.1155
2	24.425	1635.385	40.00	-189.949	0.1162
3	36.663	1633.055	60.00	-190.783	0.1168
4	48.919	1630.712	80.00	-191.618	0.1175
5	61.192	1628.355	100.00	-192.454	0.1182
6	73.483	1625.985	120.00	-193.292	0.1189
7	85.793	1623.600	140.00	-194.131	0.1196
8	98.120	1621.143	160.00	-196.860	0.1214
9	110.466	1618.756	180.00	-196.483	0.1214
10	122.830	1616.361	200.00	-195.969	0.1212
11	135.213	1613.915	220.00	-200.621	0.1243
12	147.615	1611.407	240.00	-197.311	0.1225
13	160.036	1608.927	260.00	-199.056	0.1237
14	172.476	1606.435	280.00	-197.628	0.1230
15	184.936	1603.986	300.00	-197.107	0.1229
16	197.414	1601.559	320.00	-195.873	0.1223
17	209.912	1599.071	340.00	-195.450	0.1222
18	222.428	1596.680	360.00	-196.747	0.1232
19	234.964	1594.214	380.00	-196.231	0.1231
20	247.519	1591.789	400.00	-194.993	0.1225
21	260.094	1589.294	420.00	-195.796	0.1232
22	272.688	1586.770	440.00	-195.699	0.1233
23	285.302	1584.349	460.00	-194.848	0.1230
24	297.935	1581.825	480.00	-194.335	0.1229
25	310.588	1579.408	500.00	-194.120	0.1229
26	323.261	1576.982	520.00	-191.054	0.1212
27	335.953	1574.573	540.00	-194.439	0.1235
28	348.665	1572.122	560.00	-197.310	0.1255
29	361.397	1569.581	580.00	-197.745	0.1260
30	374.150	1566.951	600.00	-197.075	0.1258
31	386.924	1564.422	620.00	-194.364	0.1242
32	399.718	1561.904	640.00	-192.918	0.1235
33	412.533	1559.471	660.00	-189.927	0.1218
34	425.368	1557.060	680.00	-189.747	0.1219
35	438.222	1554.780	700.00	-185.440	0.1193
36	451.096	1552.405	720.00	-184.658	0.1190
37	463.989	1549.977	740.00	-187.798	0.1212
38	476.902	1547.506	760.00	-189.745	0.1226
39	489.836	1545.103	780.00	-194.213	0.1257
40	502.791	1542.525	800.00	-193.100	0.1252
41	515.768	1540.021	820.00	-194.255	0.1261
42	528.765	1537.457	840.00	-192.449	0.1252

43	541.785	1534.957	860.00	-191.696	0.1249
44	554.825	1532.463	880.00	-190.943	0.1246
45	567.886	1529.975	900.00	-190.188	0.1243
46	580.969	1527.492	920.00	-189.433	0.1240
47	594.073	1525.016	940.00	-188.676	0.1237
48	607.198	1522.546	960.00	-187.915	0.1234

Table A-8. Velocity Data for the APFSDS Projectile, Shot No. 8 (elevated)

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	14:32:06.617	1-4	8

B2 CASSIDY 40MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted
(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1639.096	0.00	-209.588	0.1279
1	61.248	1626.387	100.00	-205.418	0.1263
2	122.972	1613.837	200.00	-201.214	0.1247
3	185.176	1601.453	300.00	-196.979	0.1230
4	247.859	1589.304	400.00	-192.683	0.1212
5	311.020	1577.211	500.00	-189.885	0.1204
6	374.665	1565.279	600.00	-186.963	0.1194
7	438.796	1553.357	700.00	-184.844	0.1190
8	503.420	1541.471	800.00	-182.241	0.1182
9	568.543	1529.679	900.00	-180.140	0.1178
10	634.168	1517.942	1000.00	-177.947	0.1172
11	700.302	1506.254	1100.00	-176.168	0.1170
12	766.951	1494.582	1200.00	-174.677	0.1169
13	834.121	1482.904	1300.00	-173.472	0.1170
14	901.824	1471.196	1400.00	-172.540	0.1173
15	970.069	1459.424	1500.00	-170.984	0.1172
16	1038.866	1447.692	1600.00	-168.770	0.1166
17	1108.221	1436.094	1700.00	-166.392	0.1159
18	1178.134	1424.589	1800.00	-164.829	0.1157
19	1248.615	1413.057	1900.00	-163.350	0.1156
20	1319.676	1401.491	2000.00	-162.146	0.1157
21	1391.325	1389.889	2100.00	-161.352	0.1161
22	1463.575	1378.310	2200.00	-159.924	0.1160
23	1536.435	1366.685	2300.00	-159.153	0.1165
24	1609.919	1355.017	2400.00	-158.387	0.1169
25	1684.040	1343.315	2500.00	-157.179	0.1170
26	1758.810	1331.590	2600.00	-156.388	0.1174
27	1834.241	1319.844	2700.00	-155.610	0.1179
28	1910.349	1308.030	2800.00	-154.988	0.1185
29	1987.150	1296.123	2900.00	-154.290	0.1190
30	2064.660	1284.203	3000.00	-152.954	0.1191
31	2142.893	1272.291	3100.00	-151.473	0.1191
32	2221.861	1260.404	3200.00	-150.078	0.1191
33	2301.578	1248.491	3300.00	-148.724	0.1191
34	2382.058	1236.575	3400.00	-147.286	0.1191
35	2463.318	1224.665	3500.00	-145.891	0.1191
36	2545.373	1212.762	3600.00	-144.316	0.1190
37	2628.237	1200.860	3700.00	-142.965	0.1191
38	2711.925	1188.973	3800.00	-141.537	0.1190
39	2796.456	1177.061	3900.00	-139.973	0.1189
40	2881.845	1165.189	4000.00	-138.506	0.1189
41	2968.109	1153.317	4100.00	-137.008	0.1188

42	3055.264	1141.381	4200.00	-135.838	0.1190
43	3143.338	1129.486	4300.00	-134.094	0.1187
44	3232.340	1117.649	4400.00	-132.459	0.1185
45	3322.288	1105.875	4500.00	-130.748	0.1182
46	3413.203	1093.962	4600.00	-129.780	0.1186
47	3505.112	1082.132	4700.00	-128.416	0.1187
48	3598.034	1070.268	4800.00	-126.631	0.1183
49	3691.989	1058.456	4900.00	-124.910	0.1180

Table A-9. Velocity Data for the APFSDS Projectile, Shot No. 9 (elevated)

W E I B E L S C I E N T I F I C W-1000i #5037

DATE	TIME	CHANNEL	ROUND
991027	14:41:35.239	1-4	9

B2 CASSIDY 40MM AP

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted
(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1638.931	0.00	-217.425	0.1327
1	61.262	1625.781	100.00	-211.857	0.1303
2	123.018	1612.872	200.00	-206.244	0.1279
3	185.264	1600.210	300.00	-200.586	0.1254
4	248.000	1587.805	400.00	-194.884	0.1227
5	311.222	1575.836	500.00	-189.086	0.1200
6	374.917	1564.115	600.00	-185.901	0.1189
7	439.092	1552.360	700.00	-184.470	0.1188
8	503.757	1540.473	800.00	-183.811	0.1193
9	568.926	1528.491	900.00	-183.201	0.1199
10	634.609	1516.436	1000.00	-182.273	0.1202
11	700.818	1504.359	1100.00	-180.991	0.1203
12	767.558	1492.318	1200.00	-179.284	0.1201
13	834.839	1480.327	1300.00	-177.402	0.1198
14	902.667	1468.355	1400.00	-175.613	0.1196
15	971.048	1456.416	1500.00	-173.769	0.1193
16	1039.993	1444.499	1600.00	-171.995	0.1191
17	1109.507	1432.624	1700.00	-170.310	0.1189
18	1179.599	1420.755	1800.00	-168.732	0.1188
19	1250.280	1408.889	1900.00	-167.240	0.1187
20	1321.559	1397.025	2000.00	-165.724	0.1186
21	1393.445	1385.184	2100.00	-164.571	0.1188
22	1465.949	1373.310	2200.00	-163.441	0.1190
23	1539.083	1361.398	2300.00	-162.281	0.1192
24	1612.861	1349.460	2400.00	-161.064	0.1194
25	1687.295	1337.506	2500.00	-159.811	0.1195
26	1762.397	1325.543	2600.00	-158.410	0.1195
27	1838.179	1313.618	2700.00	-156.875	0.1194
28	1914.653	1301.679	2800.00	-155.513	0.1195
29	1991.831	1289.732	2900.00	-154.144	0.1195
30	2069.728	1277.782	3000.00	-152.739	0.1195
31	2148.357	1265.835	3100.00	-151.347	0.1196
32	2227.733	1253.876	3200.00	-149.943	0.1196
33	2307.869	1241.920	3300.00	-148.493	0.1196
34	2388.779	1229.968	3400.00	-147.049	0.1196
35	2470.480	1218.019	3500.00	-145.612	0.1196
36	2552.985	1206.076	3600.00	-144.204	0.1196
37	2636.312	1194.123	3700.00	-142.852	0.1196
38	2720.478	1182.157	3800.00	-141.508	0.1197
39	2805.500	1170.189	3900.00	-140.116	0.1197
40	2891.397	1158.214	4000.00	-138.714	0.1198
41	2978.186	1146.237	4100.00	-137.272	0.1198

42	3065.888	1134.264	4200.00	-135.795	0.1197
43	3154.519	1122.299	4300.00	-134.312	0.1197
44	3244.100	1110.346	4400.00	-132.837	0.1196
45	3334.650	1098.400	4500.00	-131.404	0.1196
46	3426.191	1086.432	4600.00	-130.009	0.1197
47	3518.745	1074.468	4700.00	-128.478	0.1196
48	3612.337	1062.515	4800.00	-126.867	0.1194
49	3706.986	1050.582	4900.00	-125.048	0.1190
50	3802.714	1038.715	5000.00	-123.150	0.1186
51	3899.540	1026.898	5100.00	-121.252	0.1181
52	3997.485	1015.111	5200.00	-119.273	0.1175
53	4096.570	1003.391	5300.00	-117.148	0.1168
54	4196.815	991.763	5400.00	-115.074	0.1160
55	4298.236	980.233	5500.00	-113.133	0.1154
56	4400.855	968.745	5600.00	-111.685	0.1153
57	4504.698	957.235	5700.00	-110.888	0.1158
58	4609.804	945.629	5800.00	-110.424	0.1168
59	4716.216	933.886	5900.00	-109.789	0.1176
60	4823.977	922.099	6000.00	-109.119	0.1183
61	4933.128	910.233	6100.00	-108.440	0.1191

Table A-10. Velocity Data for the APFSDS Projectile, Shot No. 10 (elevated)

DATA MISSING

Table A-11. Velocity Data for the GP Projectile, Shot No. 11
(BURST MODE 11-1)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	15:43:03.493	1-4	11

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1035.347	0.00	-786.170	0.7593
1	19.460	1020.222	20.00	-768.307	0.7531
2	39.209	1005.228	40.00	-750.179	0.7463
3	59.253	990.376	60.00	-731.779	0.7389
4	79.600	975.677	80.00	-713.102	0.7309
5	100.253	961.145	100.00	-694.143	0.7222
6	121.219	946.793	120.00	-674.898	0.7128
7	142.503	932.588	140.00	-656.222	0.7037
8	164.113	918.511	160.00	-637.913	0.6945
9	186.050	904.963	180.00	-615.767	0.6804
10	208.316	891.556	200.00	-596.736	0.6693
11	230.917	878.337	220.00	-579.898	0.6602
12	253.859	865.266	240.00	-563.232	0.6509
13	277.147	852.356	260.00	-546.389	0.6410
14	300.789	839.632	280.00	-529.521	0.6307
15	324.789	827.119	300.00	-512.504	0.6196
16	349.151	814.846	320.00	-495.586	0.6082
17	373.879	802.812	340.00	-478.893	0.5965
18	398.977	791.051	360.00	-462.494	0.5847
19	424.446	779.555	380.00	-446.495	0.5728
20	450.288	768.294	400.00	-431.908	0.5622
21	476.510	757.196	420.00	-418.828	0.5531
22	503.116	746.265	440.00	-406.533	0.5448
23	530.112	735.491	460.00	-394.908	0.5369
24	557.504	724.863	480.00	-383.946	0.5297
25	585.298	714.361	500.00	-373.700	0.5231
26	613.501	703.983	520.00	-363.556	0.5164
27	642.120	693.741	540.00	-354.040	0.5103
28	671.161	683.636	560.00	-345.099	0.5048
29	700.633	673.641	580.00	-337.296	0.5007
30	730.543	663.723	600.00	-331.063	0.4988
31	760.905	653.762	620.00	-325.185	0.4974
32	791.732	643.831	640.00	-319.217	0.4958
33	823.038	633.934	660.00	-313.156	0.4940
34	854.835	624.076	680.00	-306.999	0.4919
35	887.137	614.262	700.00	-300.743	0.4896

Table A-12. Velocity Data for the GP Projectile, Shot No. 12
(BURST MODE #11-2)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	15:43:03.493	1-4	12

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Time Offset : 1060.000 ms.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1041.321	0.00	-800.520	0.7688
1	19.349	1026.025	20.00	-780.519	0.7607
2	38.987	1010.897	40.00	-760.220	0.7520
3	58.919	995.949	60.00	-739.617	0.7426
4	79.152	981.197	80.00	-718.703	0.7325
5	99.688	966.655	100.00	-697.476	0.7215
6	120.533	952.341	120.00	-675.929	0.7098
7	141.691	938.289	140.00	-653.976	0.6970
8	163.164	924.601	160.00	-632.984	0.6846
9	184.954	911.137	180.00	-613.846	0.6737
10	207.067	897.809	200.00	-596.179	0.6640
11	229.509	884.653	220.00	-581.989	0.6579
12	252.285	871.641	240.00	-566.134	0.6495
13	275.402	858.771	260.00	-551.255	0.6419
14	298.865	846.025	280.00	-536.719	0.6344
15	322.683	833.405	300.00	-522.738	0.6272
16	346.863	820.927	320.00	-508.914	0.6199
17	371.411	808.614	340.00	-494.962	0.6121
18	396.332	796.473	360.00	-480.920	0.6038
19	421.633	784.589	380.00	-466.039	0.5940
20	447.319	772.743	400.00	-453.666	0.5871
21	473.399	761.077	420.00	-440.554	0.5789
22	499.878	749.604	440.00	-427.263	0.5700
23	526.762	738.315	460.00	-414.347	0.5612
24	554.058	727.207	480.00	-401.816	0.5526
25	581.770	716.249	500.00	-389.319	0.5436
26	609.906	705.483	520.00	-376.773	0.5341
27	638.471	694.907	540.00	-364.829	0.5250
28	667.470	684.520	560.00	-353.158	0.5159
29	696.908	674.331	580.00	-341.941	0.5071
30	726.789	664.397	600.00	-334.214	0.5030
31	757.121	654.364	620.00	-327.402	0.5003
32	787.921	644.388	640.00	-320.484	0.4974
33	819.199	634.475	660.00	-313.459	0.4940

Table A-13. Velocity Data for the GP Projectile, Shot No. 13
(BURST MODE 11-3)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	15:43:03.493	1-4	13

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Time Offset : 2128.000 ms.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1037.665	0.00	-852.398	0.8215
1	19.428	1021.369	20.00	-825.174	0.8079
2	39.164	1005.356	40.00	-797.517	0.7933
3	59.215	989.647	60.00	-769.421	0.7775
4	79.584	974.265	80.00	-740.878	0.7605
5	100.273	959.237	100.00	-711.887	0.7421
6	121.285	944.589	120.00	-682.445	0.7225
7	142.619	930.629	140.00	-650.276	0.6988
8	164.268	917.101	160.00	-625.524	0.6821
9	186.237	903.720	180.00	-605.465	0.6700
10	208.532	890.497	200.00	-587.306	0.6595
11	231.159	877.388	220.00	-571.571	0.6515
12	254.123	864.515	240.00	-556.168	0.6433
13	277.430	851.764	260.00	-540.642	0.6347
14	301.087	839.160	280.00	-525.248	0.6259
15	325.099	826.722	300.00	-509.367	0.6161
16	349.472	814.481	320.00	-493.696	0.6062
17	374.211	802.465	340.00	-478.262	0.5960
18	399.320	790.688	360.00	-462.967	0.5855
19	424.801	779.174	380.00	-448.068	0.5751
20	450.657	767.874	400.00	-434.614	0.5660
21	476.895	756.665	420.00	-423.003	0.5590
22	503.522	745.579	440.00	-412.333	0.5530
23	530.547	734.611	460.00	-402.123	0.5474
24	557.977	723.720	480.00	-391.960	0.5416
25	585.820	712.940	500.00	-381.557	0.5352
26	614.085	702.287	520.00	-370.838	0.5280
27	642.779	691.797	540.00	-360.005	0.5204
28	671.907	681.475	560.00	-348.989	0.5121
29	701.474	671.396	580.00	-340.371	0.5070
30	731.489	661.310	600.00	-331.828	0.5018
31	761.963	651.331	620.00	-323.154	0.4961
32	792.905	641.470	640.00	-314.346	0.4900
33	824.323	631.735	660.00	-305.403	0.4834
34	856.225	622.139	680.00	-296.321	0.4763

Table A-14. Velocity Data for the GP Projectile, Shot No. 14
(BURST MODE 12-1)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	16:04:51.115	1-4	14

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1037.955	0.00	-809.709	0.7801
1	19.414	1022.463	20.00	-786.262	0.7690
2	39.123	1007.201	40.00	-762.461	0.7570
3	59.129	992.189	60.00	-738.299	0.7441
4	79.439	977.444	80.00	-713.771	0.7302
5	100.054	962.986	100.00	-688.874	0.7154
6	120.976	948.980	120.00	-666.187	0.7020
7	142.204	935.363	140.00	-643.289	0.6877
8	163.744	921.457	160.00	-633.362	0.6874
9	185.612	907.817	180.00	-614.353	0.6767
10	207.808	894.365	200.00	-595.078	0.6654
11	230.337	881.238	220.00	-574.599	0.6520
12	253.201	868.356	240.00	-557.245	0.6417
13	276.403	855.715	260.00	-542.513	0.6340
14	299.949	843.106	280.00	-526.347	0.6243
15	323.848	830.673	300.00	-510.932	0.6151
16	348.104	818.444	320.00	-495.946	0.6060
17	372.722	806.460	340.00	-480.309	0.5956
18	397.705	794.730	360.00	-464.841	0.5849
19	423.054	783.185	380.00	-451.827	0.5769
20	448.780	771.715	400.00	-440.015	0.5702
21	474.889	760.385	420.00	-428.027	0.5629
22	501.387	749.206	440.00	-415.860	0.5551

Table A-15. Velocity Data for the GP Projectile, Shot No. 15
(BURST MODE 12-2)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	16:04:51.115	1-4	15

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Time Offset : 425.000 ms.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1044.489	0.00	-820.759	0.7858
1	19.293	1028.876	20.00	-797.773	0.7754
2	38.879	1013.480	40.00	-774.438	0.7641
3	58.762	998.317	60.00	-750.749	0.7520
4	78.948	983.405	80.00	-726.698	0.7390
5	99.439	968.765	100.00	-702.285	0.7249
6	120.238	954.494	120.00	-677.444	0.7097
7	141.347	940.516	140.00	-655.936	0.6974
8	162.769	926.747	160.00	-636.234	0.6865
9	184.510	913.130	180.00	-618.018	0.6768
10	206.576	899.690	200.00	-600.295	0.6672
11	228.971	886.486	220.00	-582.152	0.6567
12	251.700	873.474	240.00	-565.445	0.6474
13	274.766	860.672	260.00	-550.660	0.6398
14	298.178	847.950	280.00	-534.962	0.6309
15	321.941	835.393	300.00	-518.438	0.6206
16	346.061	823.055	320.00	-501.491	0.6093
17	370.541	810.983	340.00	-484.147	0.5970
18	395.383	799.265	360.00	-466.900	0.5842
19	420.588	787.748	380.00	-452.105	0.5739
20	446.162	776.377	400.00	-438.527	0.5648
21	472.111	765.173	420.00	-425.120	0.5556
22	498.439	754.160	440.00	-411.515	0.5457

Table A-16. Velocity Data for the GP Projectile, Shot No. 16
(BURST MODE 12-3)

W E I B E L S C I E N T I F I C W-1000i #5030

DATE	TIME	CHANNEL	ROUND
991027	16:04:51.115	1-4	16

B2 CASSIDY 40MM GPI BURST

VELOCITY VERSUS TIME and RESULTS BASED ON REGRESSION ANALYSIS.

Time Offset : 1080.000 ms.

Velocity Results : Adjusted

(Based on sliding fits)

NO	TIME ms.	VELOCITY m/s.	DISTANCE m	ACCL. m/s/s	RETARD. m/s/m
Muzz	0.000	1041.635	0.00	-812.103	0.7796
1	19.345	1026.124	20.00	-791.593	0.7714
2	38.983	1010.783	40.00	-770.773	0.7626
3	58.920	995.627	60.00	-749.637	0.7529
4	79.161	980.671	80.00	-728.177	0.7425
5	99.710	965.931	100.00	-706.391	0.7313
6	120.574	951.371	120.00	-685.477	0.7205
7	141.755	937.146	140.00	-662.269	0.7067
8	163.257	923.189	160.00	-641.000	0.6943
9	185.084	909.489	180.00	-620.357	0.6821
10	207.239	896.027	200.00	-600.808	0.6705
11	229.727	882.748	220.00	-582.676	0.6601
12	252.553	869.681	240.00	-565.207	0.6499
13	275.722	856.823	260.00	-549.750	0.6416
14	299.240	844.063	280.00	-533.133	0.6316
15	323.113	831.517	300.00	-515.441	0.6199
16	347.346	819.219	320.00	-497.850	0.6077
17	371.941	807.218	340.00	-480.972	0.5958
18	396.900	795.506	360.00	-464.283	0.5836
19	422.224	784.028	380.00	-450.239	0.5743
20	447.921	772.612	400.00	-437.867	0.5667
21	473.998	761.354	420.00	-425.636	0.5591
22	500.461	750.256	440.00	-413.224	0.5508

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APPENDIX B

INDIVIDUAL OVERPRESSURE PLOTS

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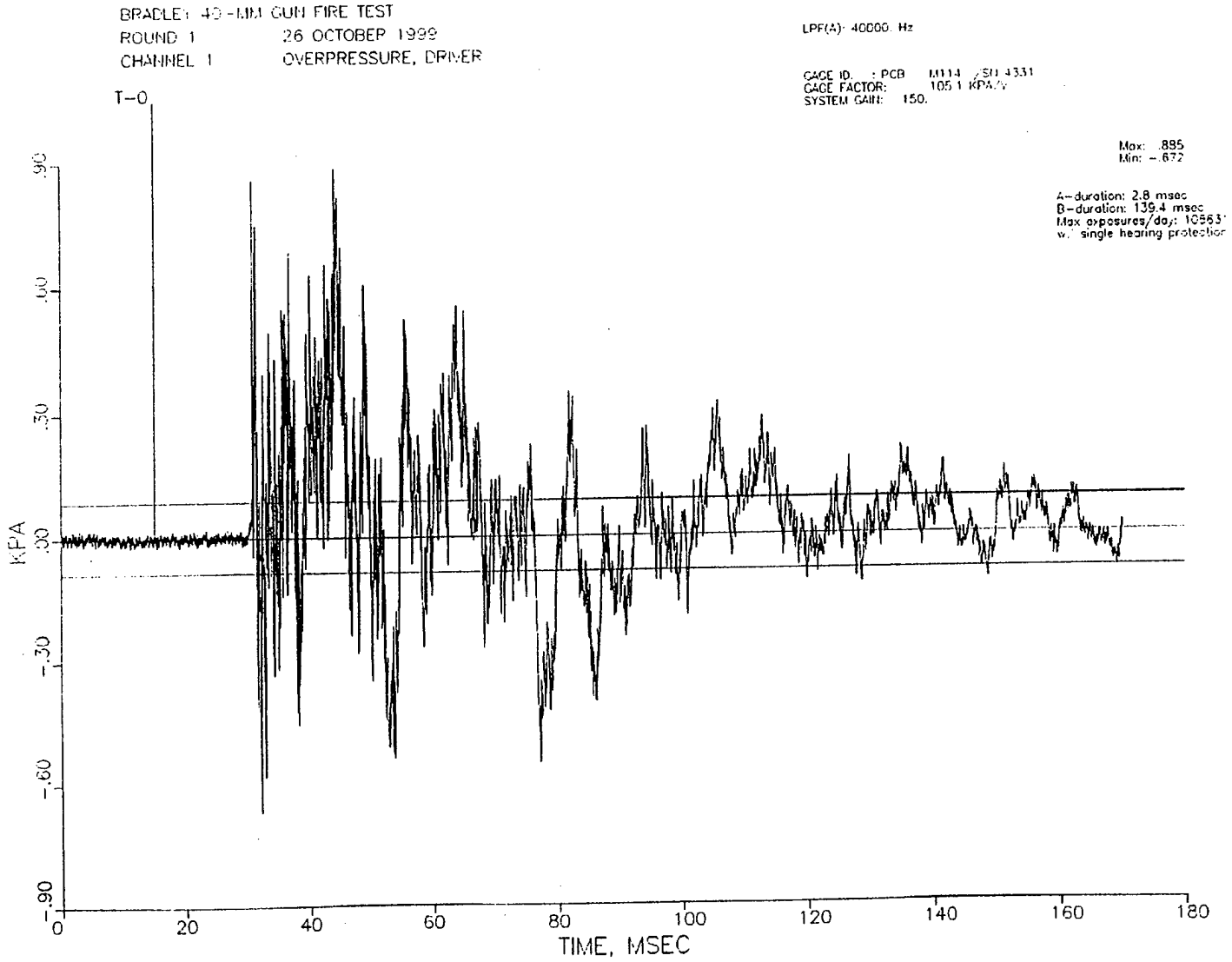

Figure B-1. Overpressure Plot for Shot 1 at the Driver Location

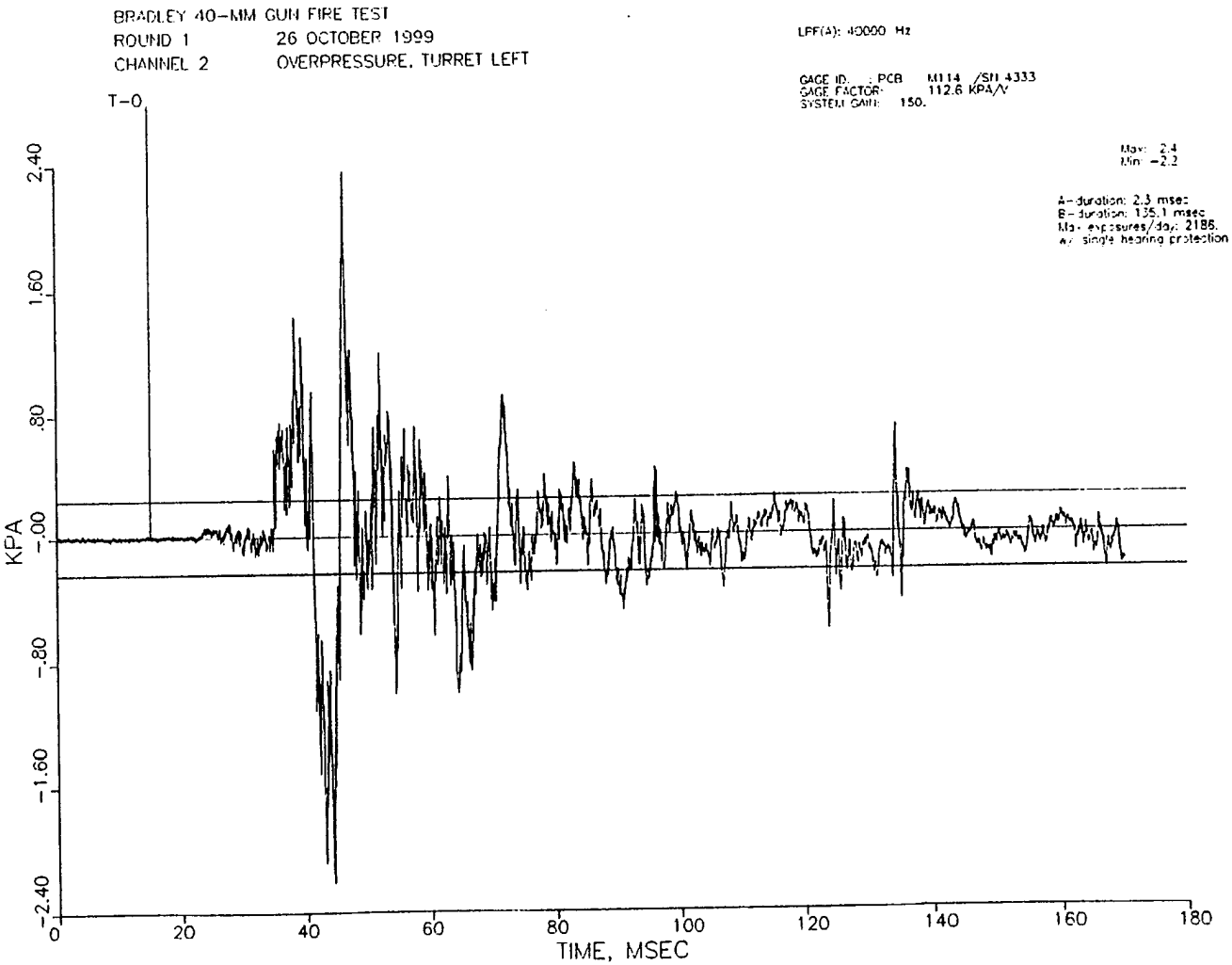

Figure B-2. Overpressure Plot for Shot 1 at the Turret Left Location

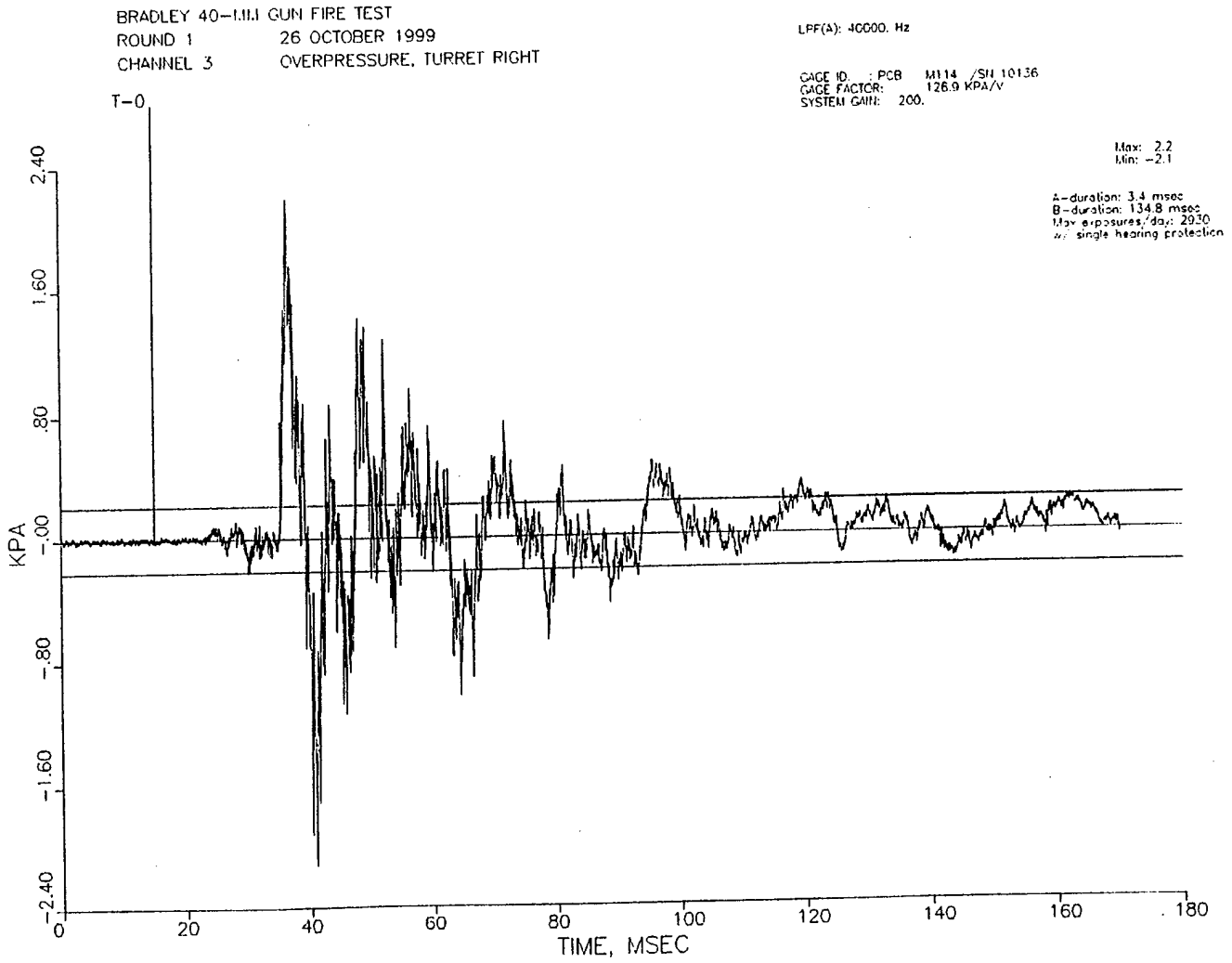

Figure B-3. Overpressure Plot for Shot 1 at the Turret Right Location

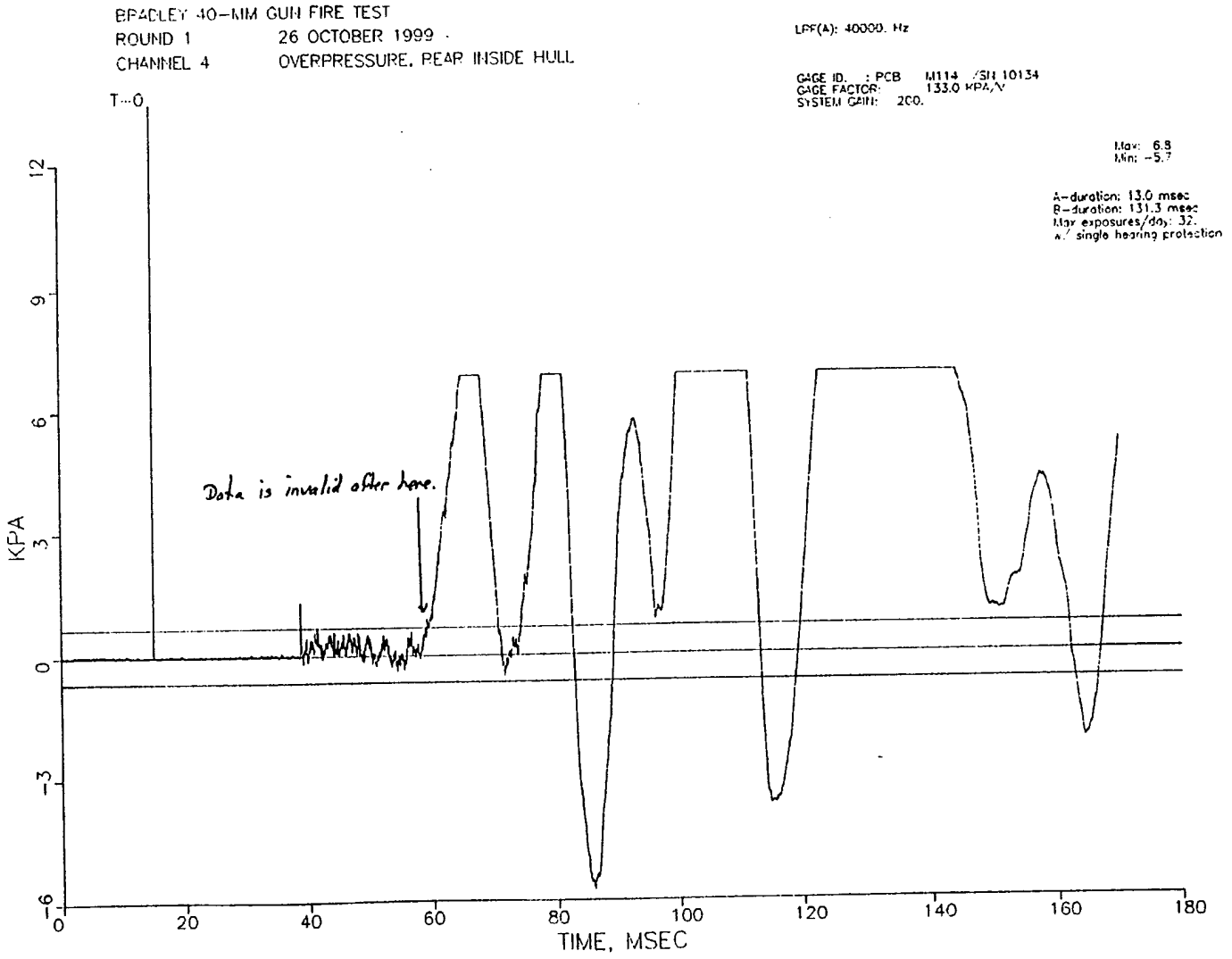

Figure B-4. Overpressure Plot for Shot 1 at the Rear Crew Area Location

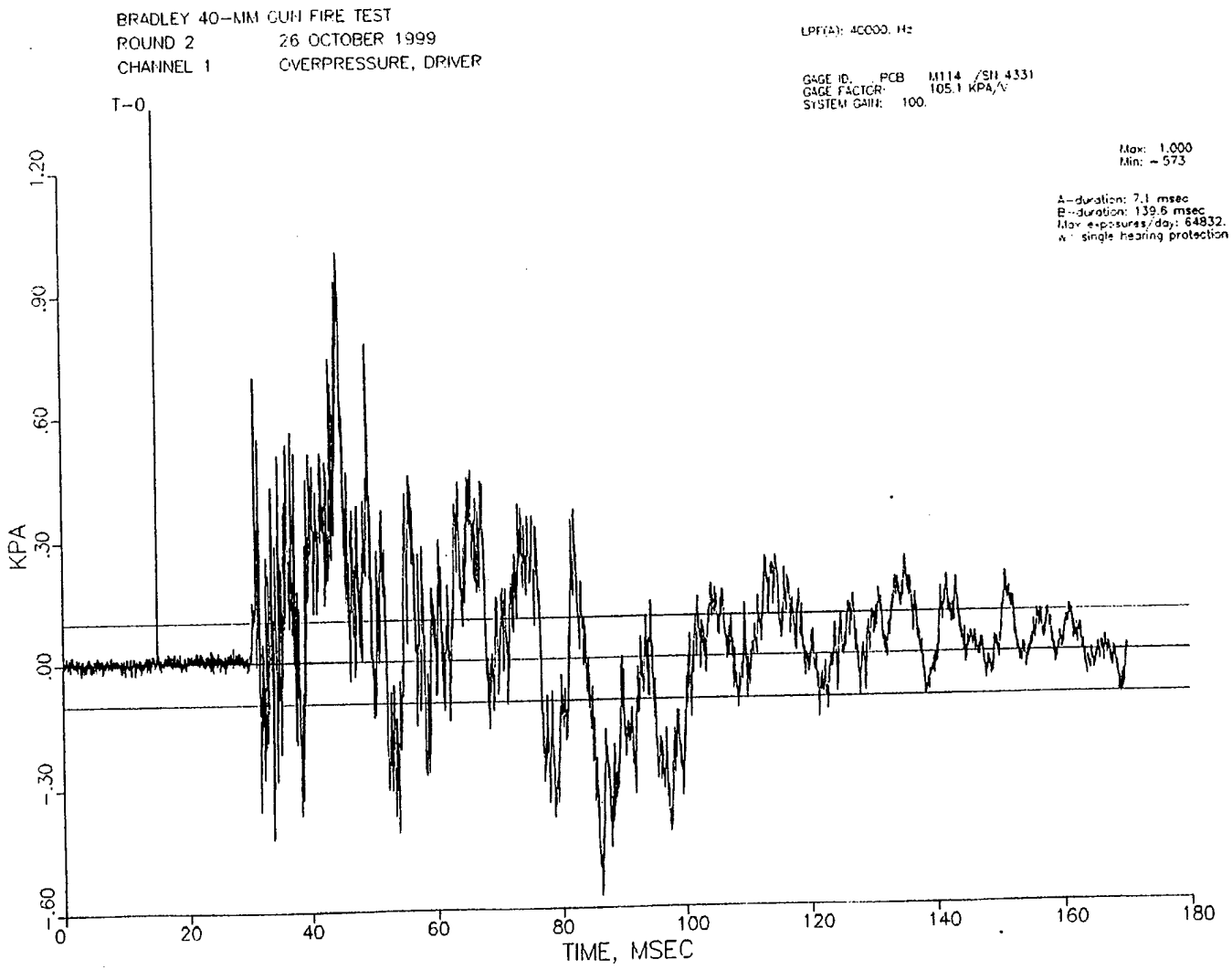

Figure B-5. Overpressure Plot for Shot 2 at the Driver Location

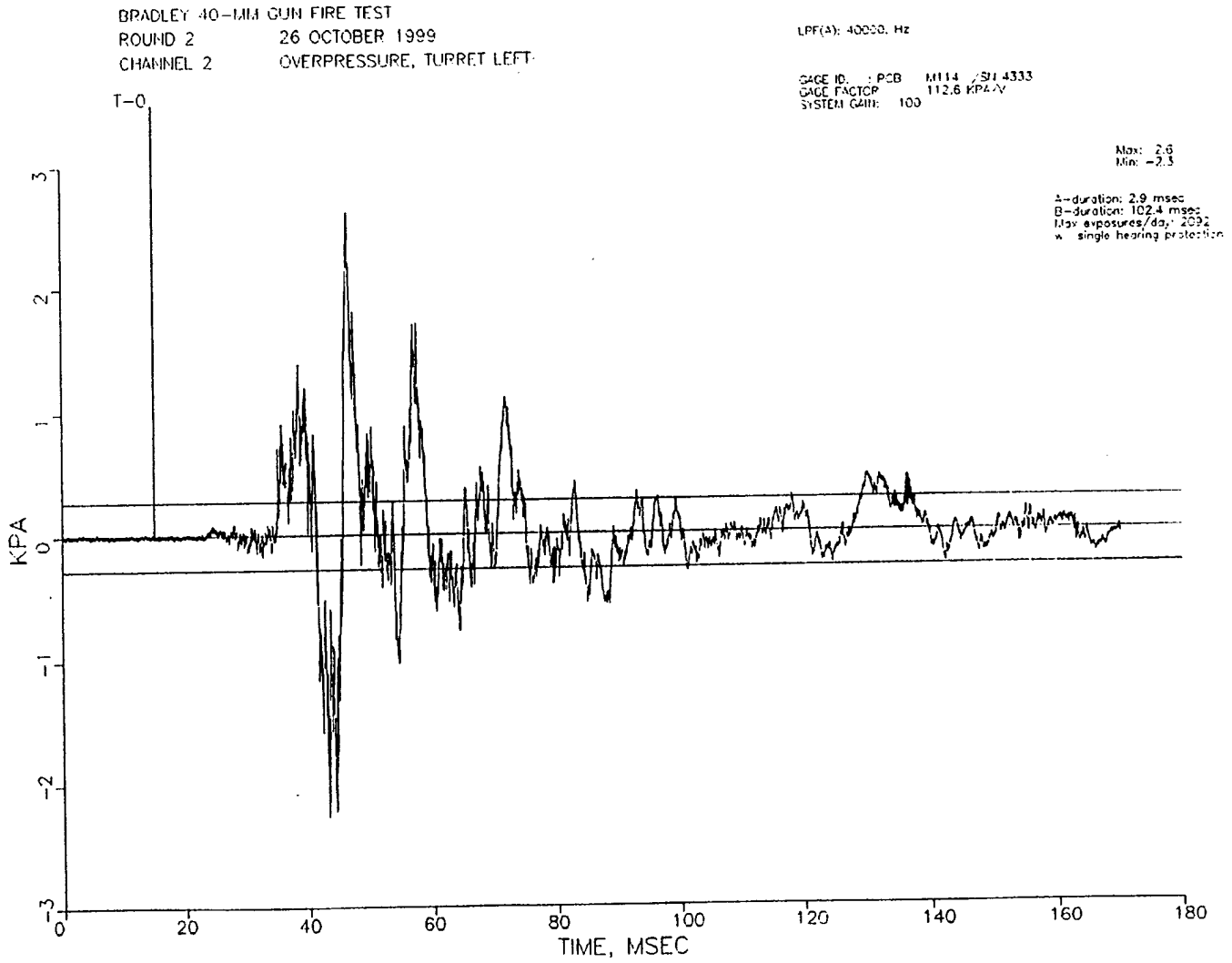

Figure B-6. Overpressure Plot for Shot 2 at the Turret Left Location

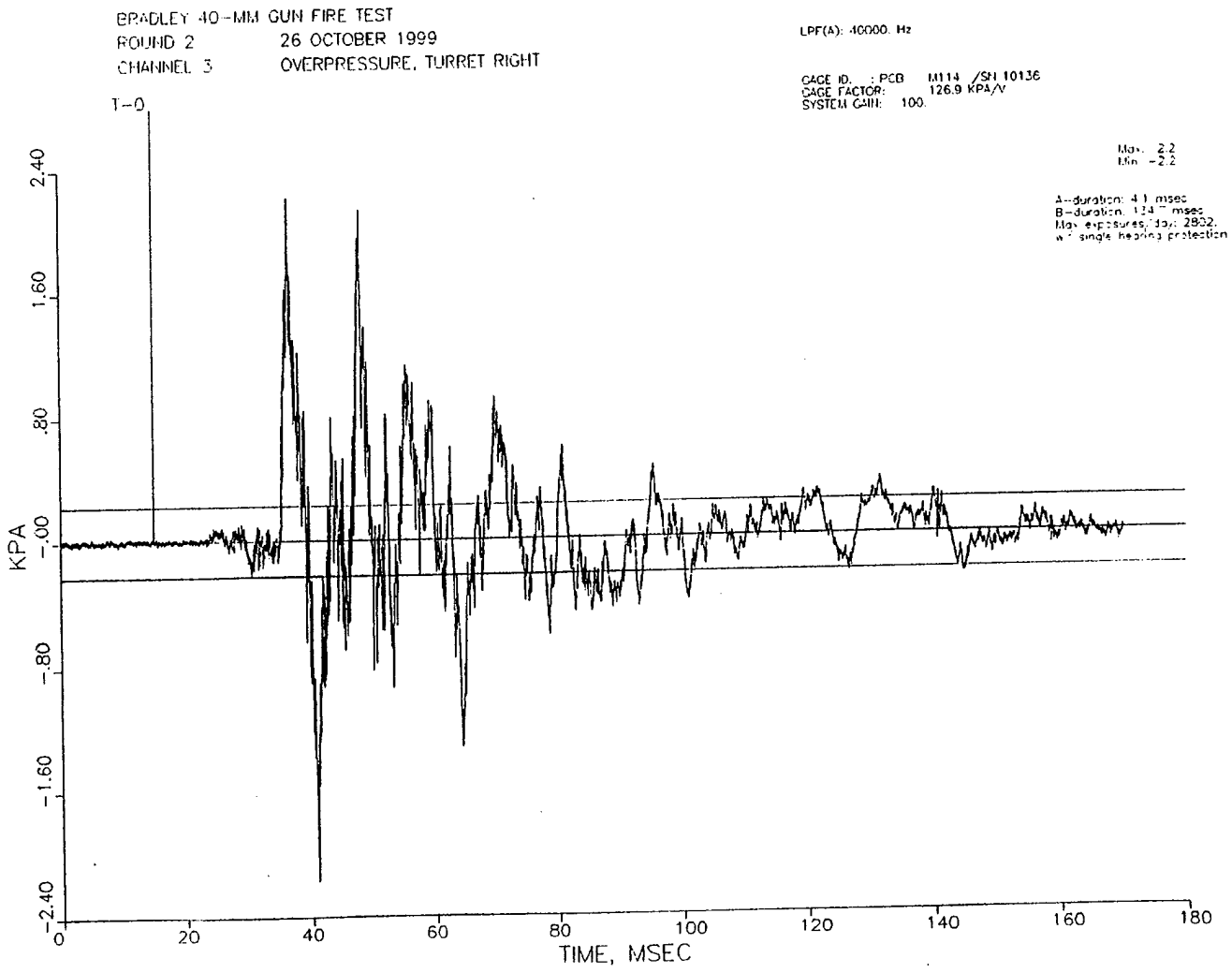

Figure B-7. Overpressure Plot for Shot 2 at the Turret Right Location

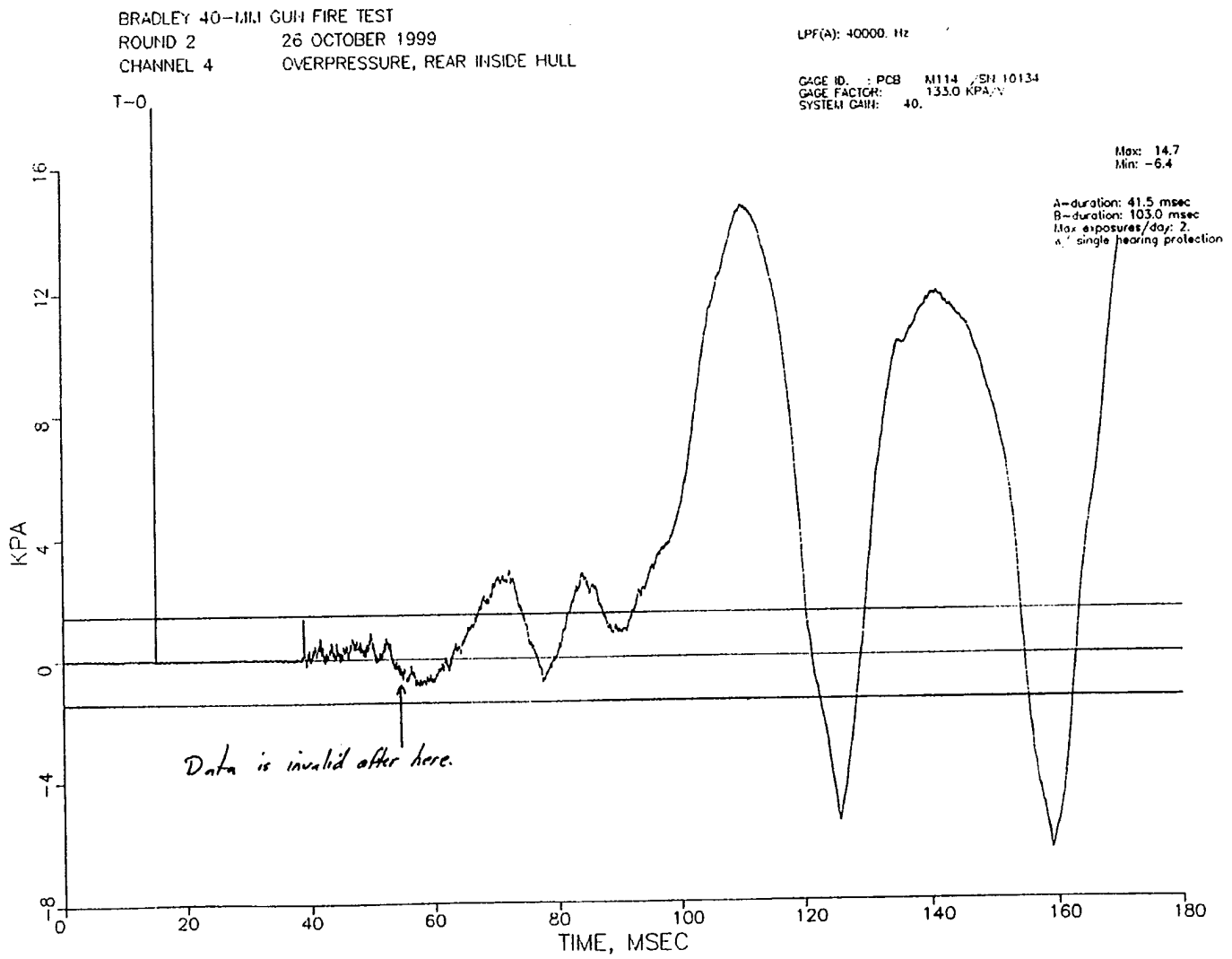

Figure B-8. Overpressure Plot for Shot 2 at the Rear Crew Area Location

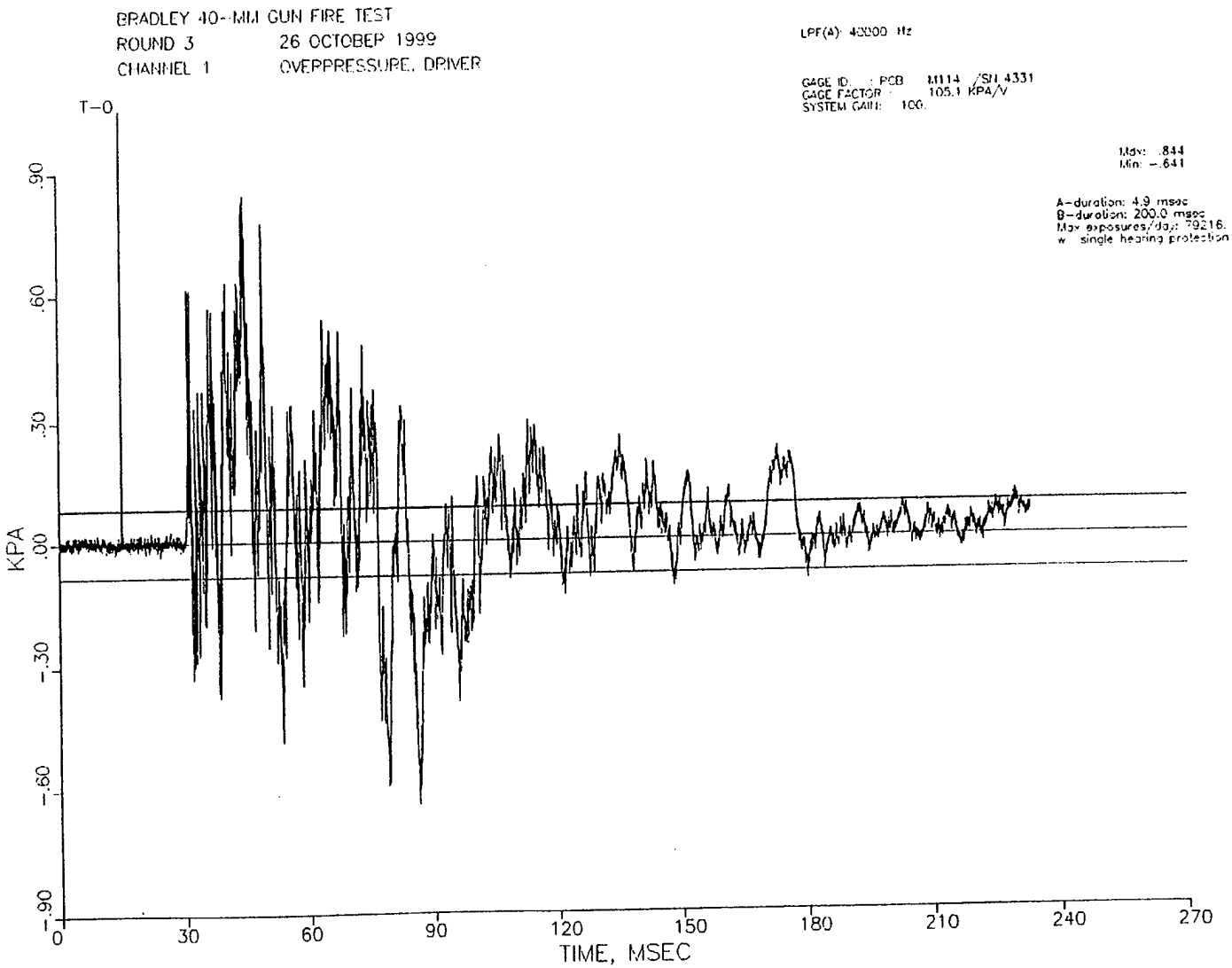

Figure B-9. Overpressure Plot for Shot 3 at the Driver Location

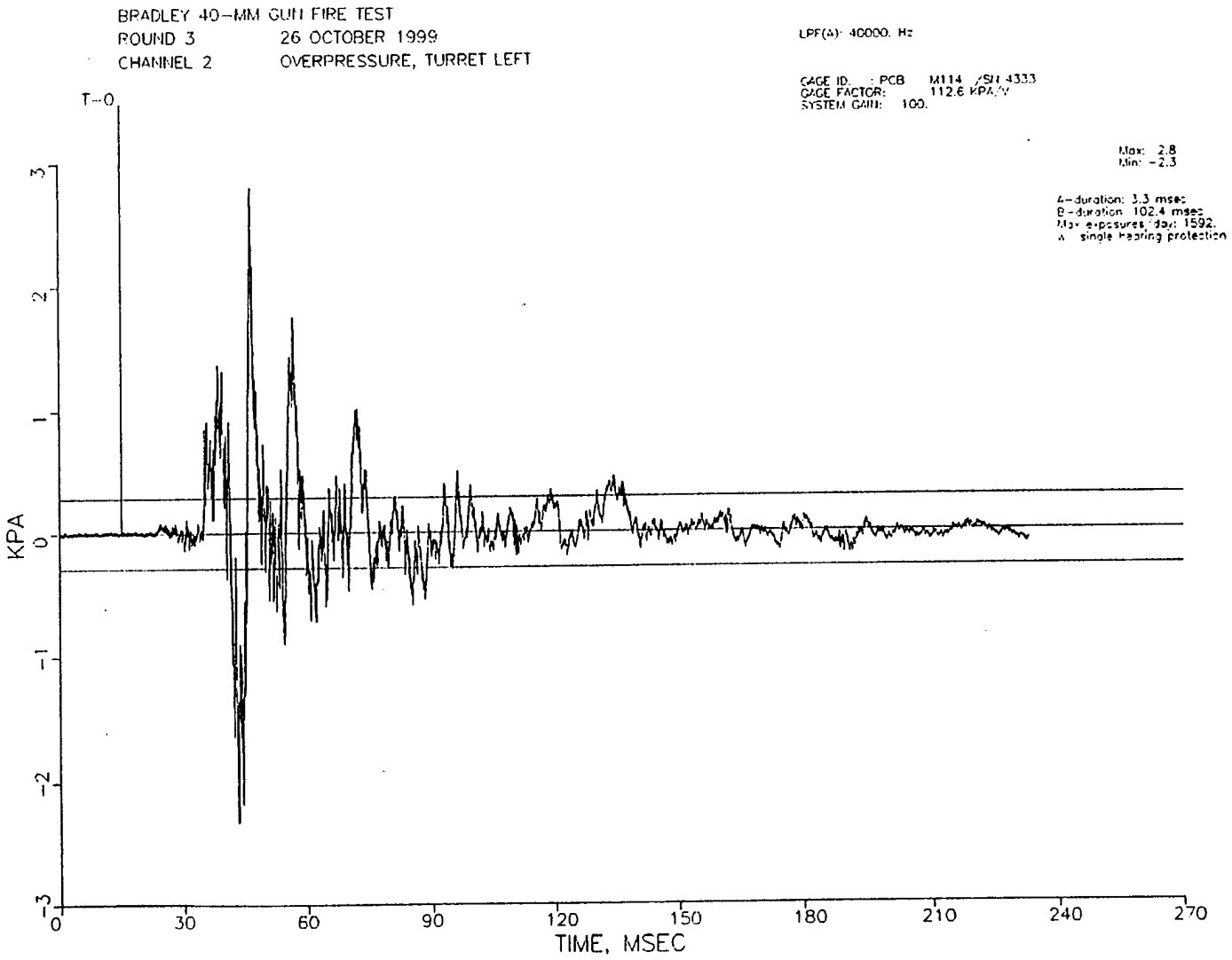

Figure B-10. Overpressure Plot for Shot 3 at the Turret Left Location

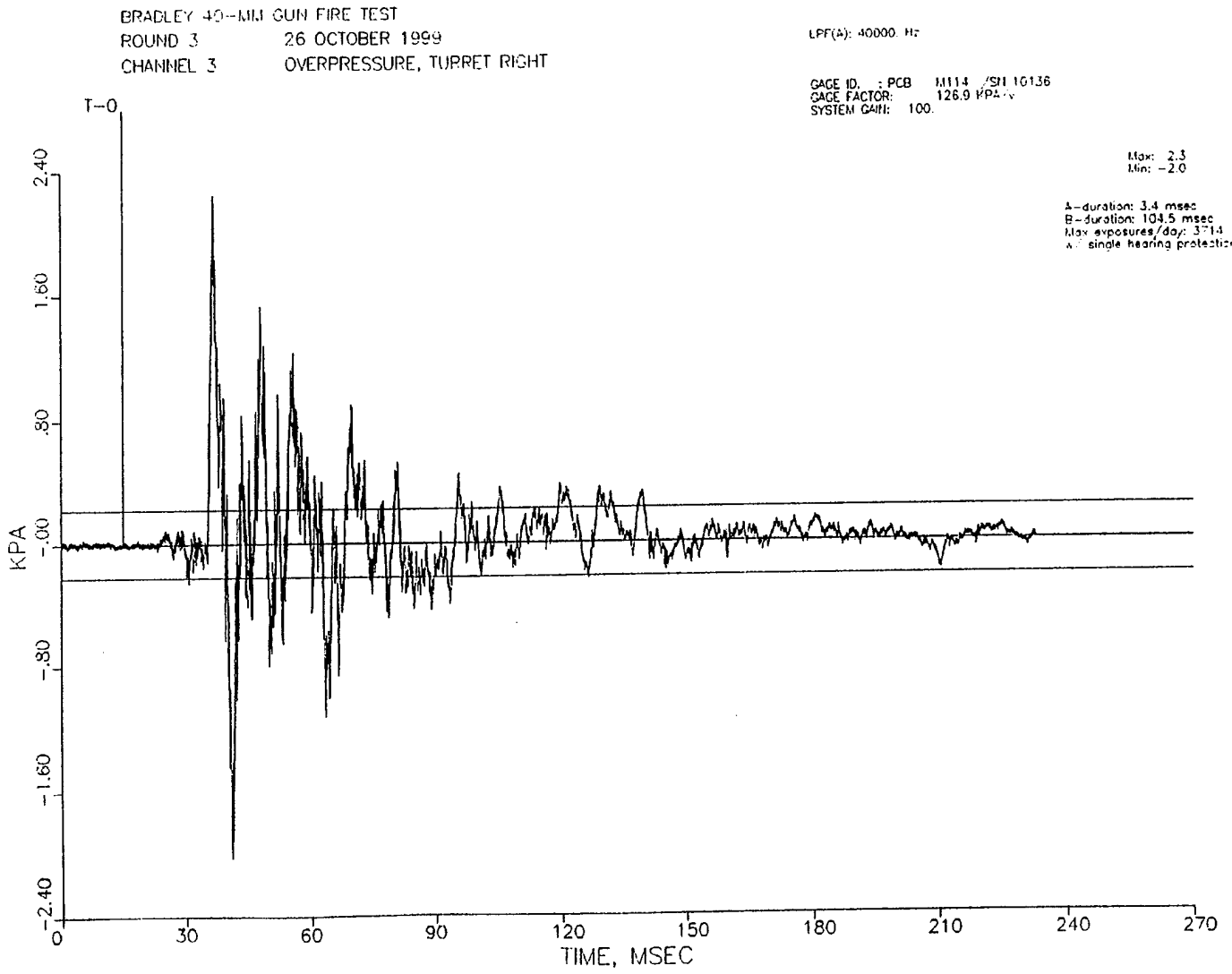

Figure B-11. Overpressure Plot for Shot 3 at the Turret Right Location

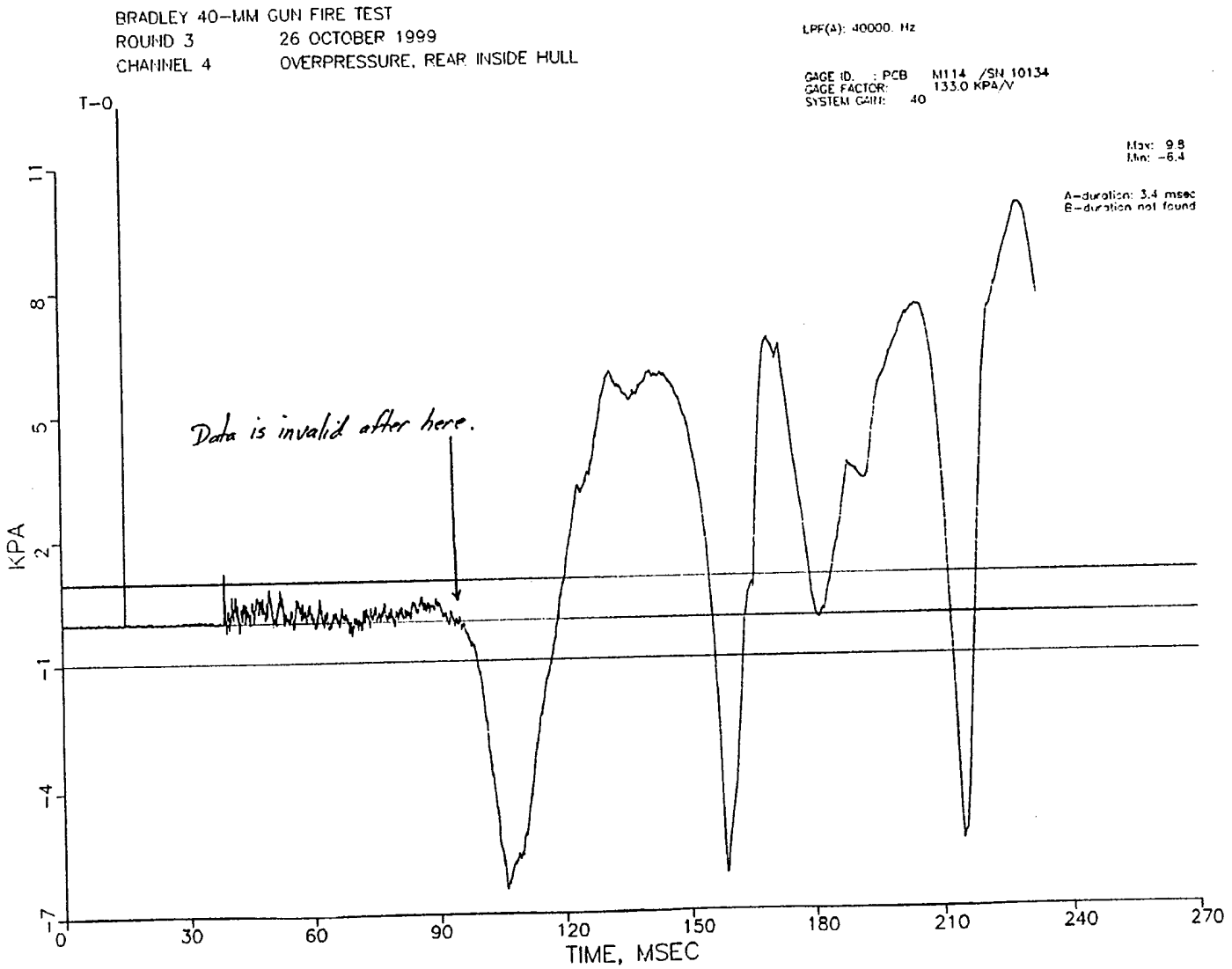

Figure B-12. Overpressure Plot for Shot 3 at the Rear Crew Area Location

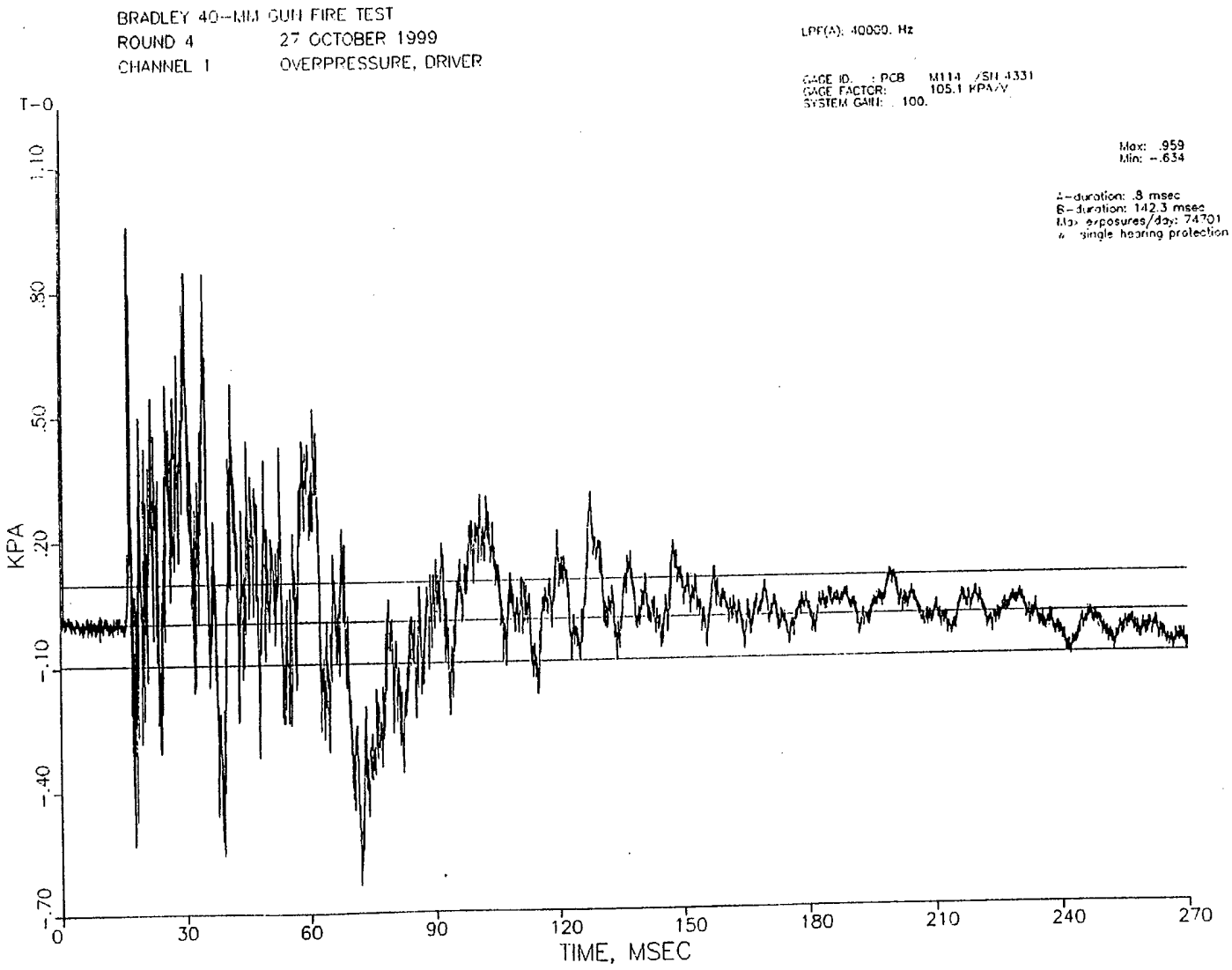

Figure B-13. Overpressure Plot for Shot 4 at the Driver Location

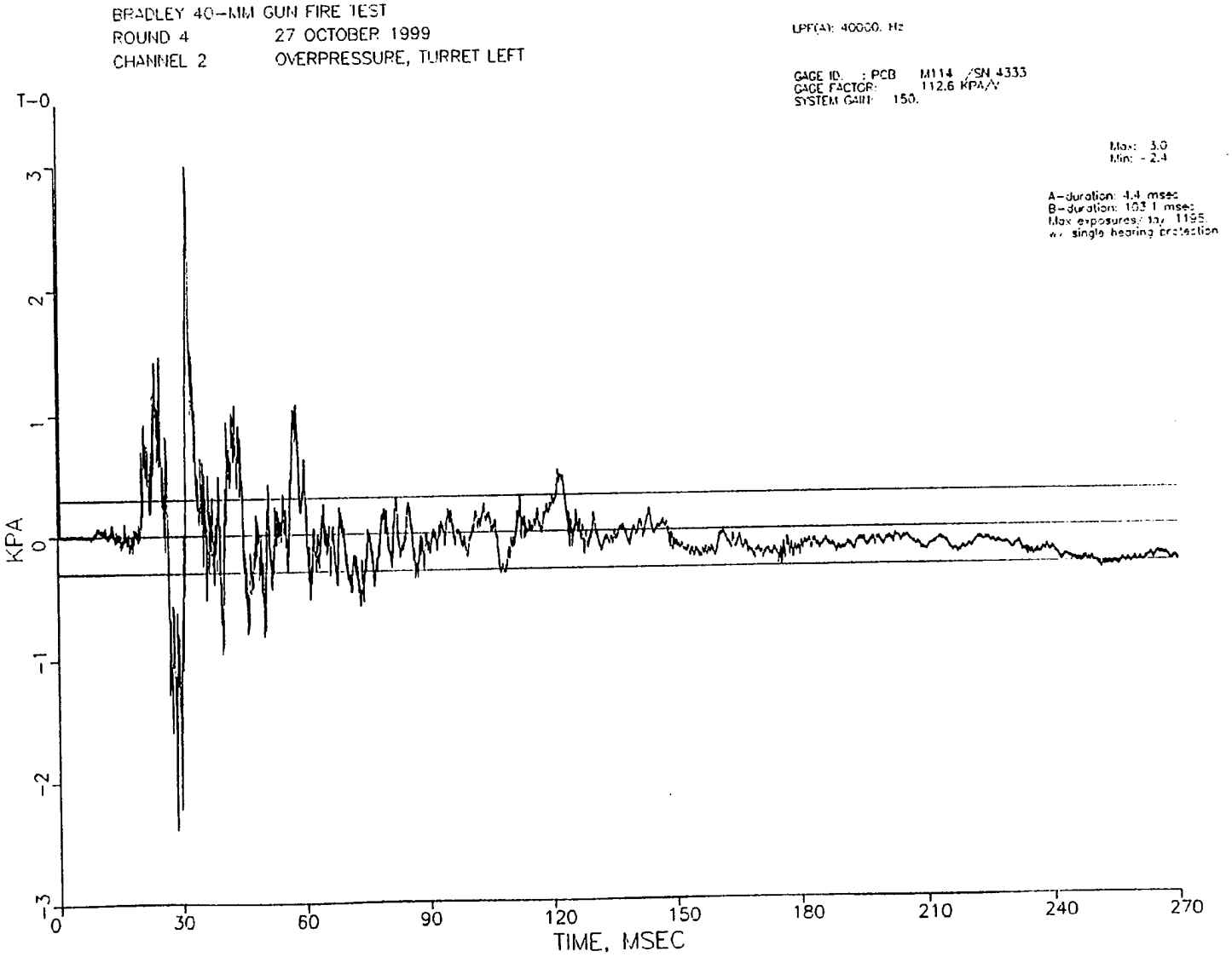

Figure B-14. Overpressure Plot for Shot 4 at the Turret Left Location

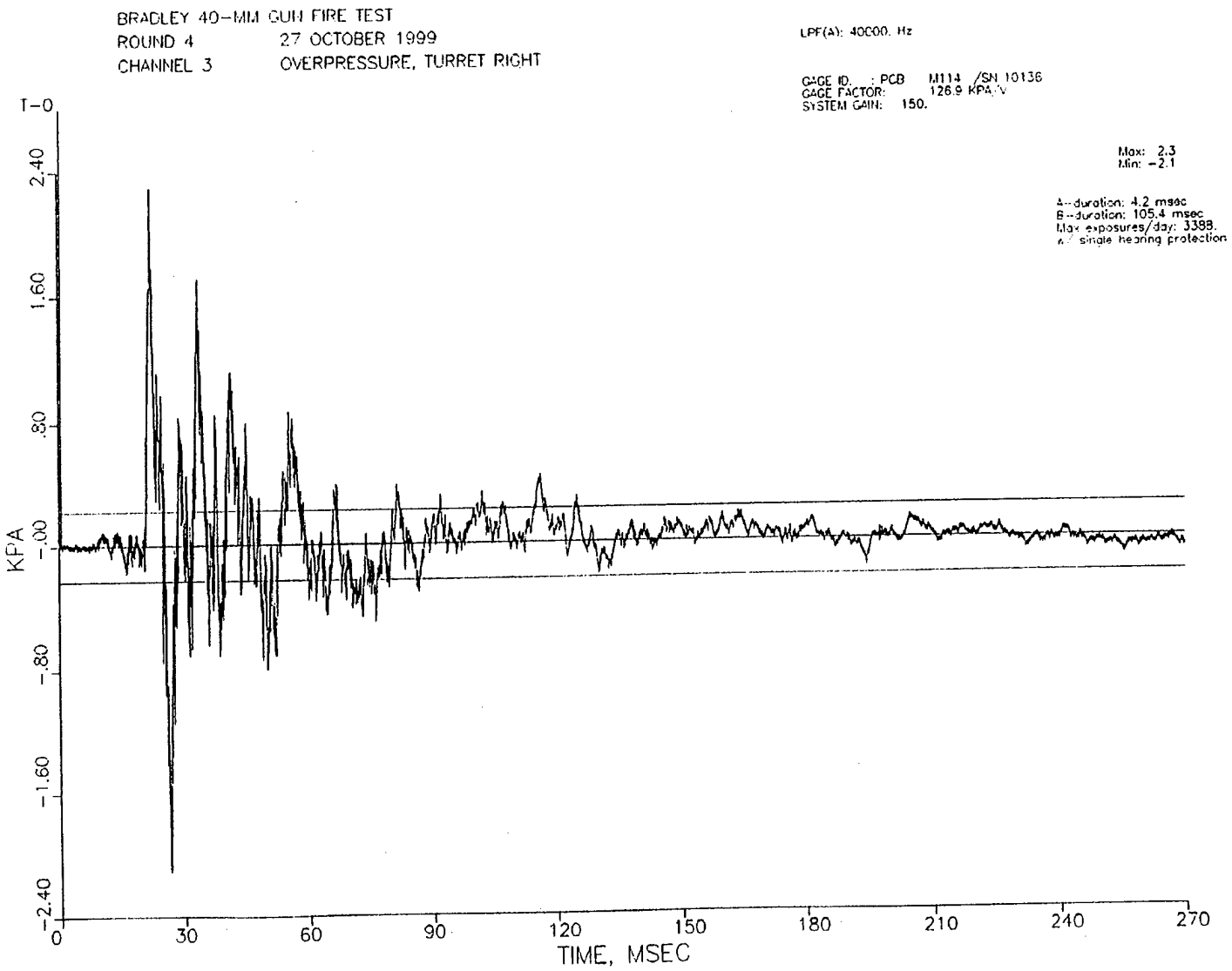

Figure B-15. Overpressure Plot for Shot 4 at the Turret Right Location

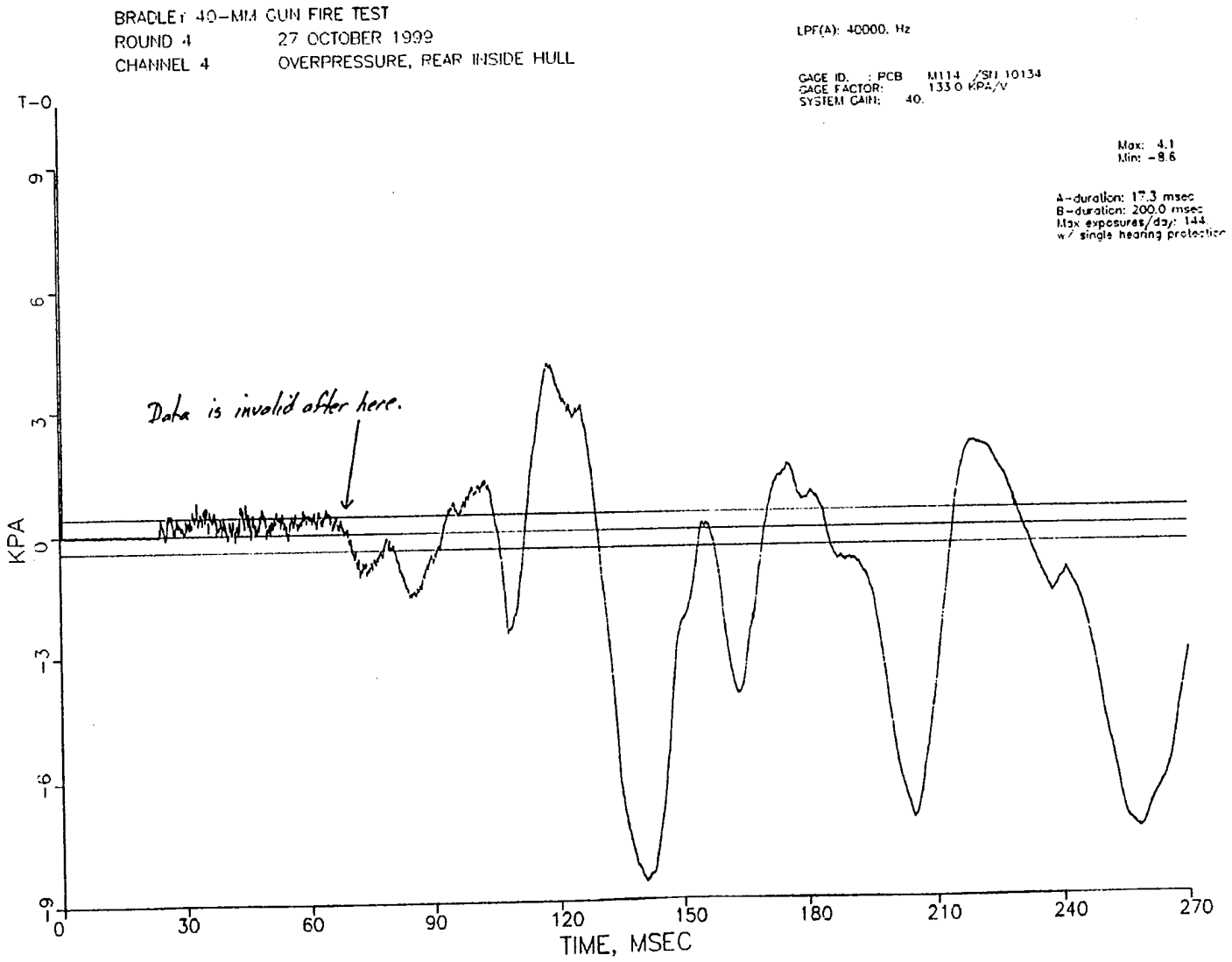

Figure B-16. Overpressure Plot for Shot 4 at the Rear Crew Area Location

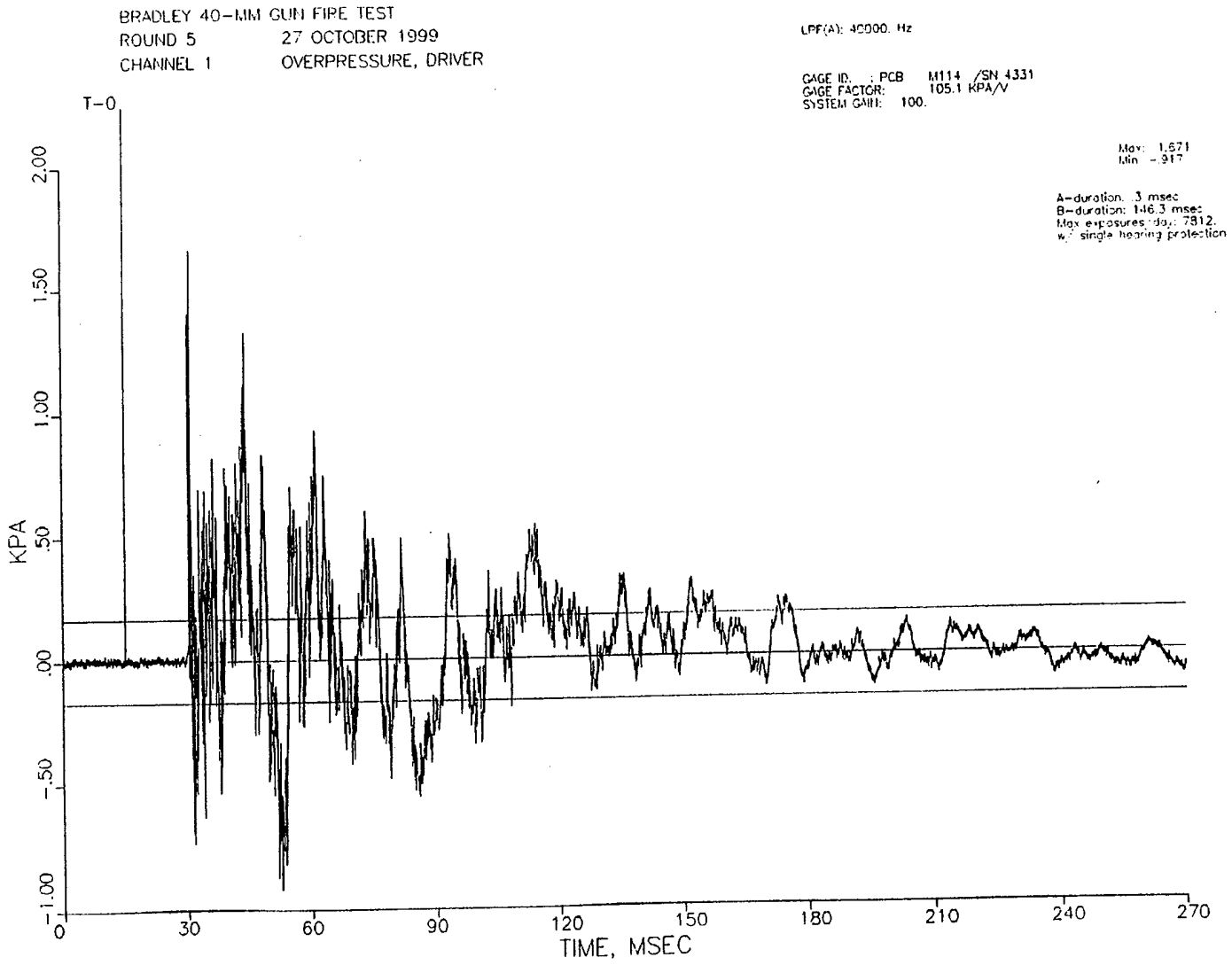

Figure B-17. Overpressure Plot for Shot 5 at the Driver Location

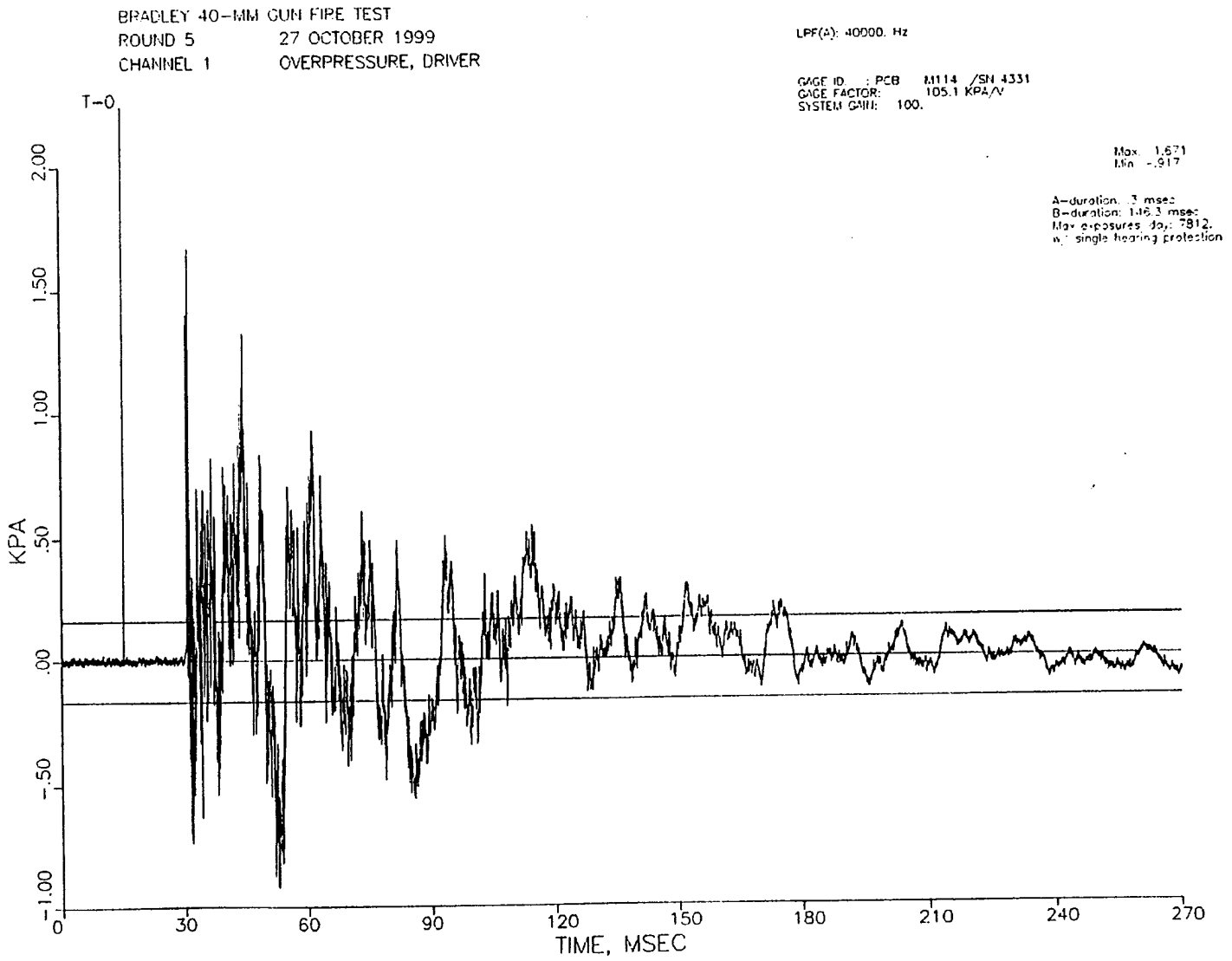

Figure B-18. Overpressure Plot for Shot 5 at the Turret Left Location

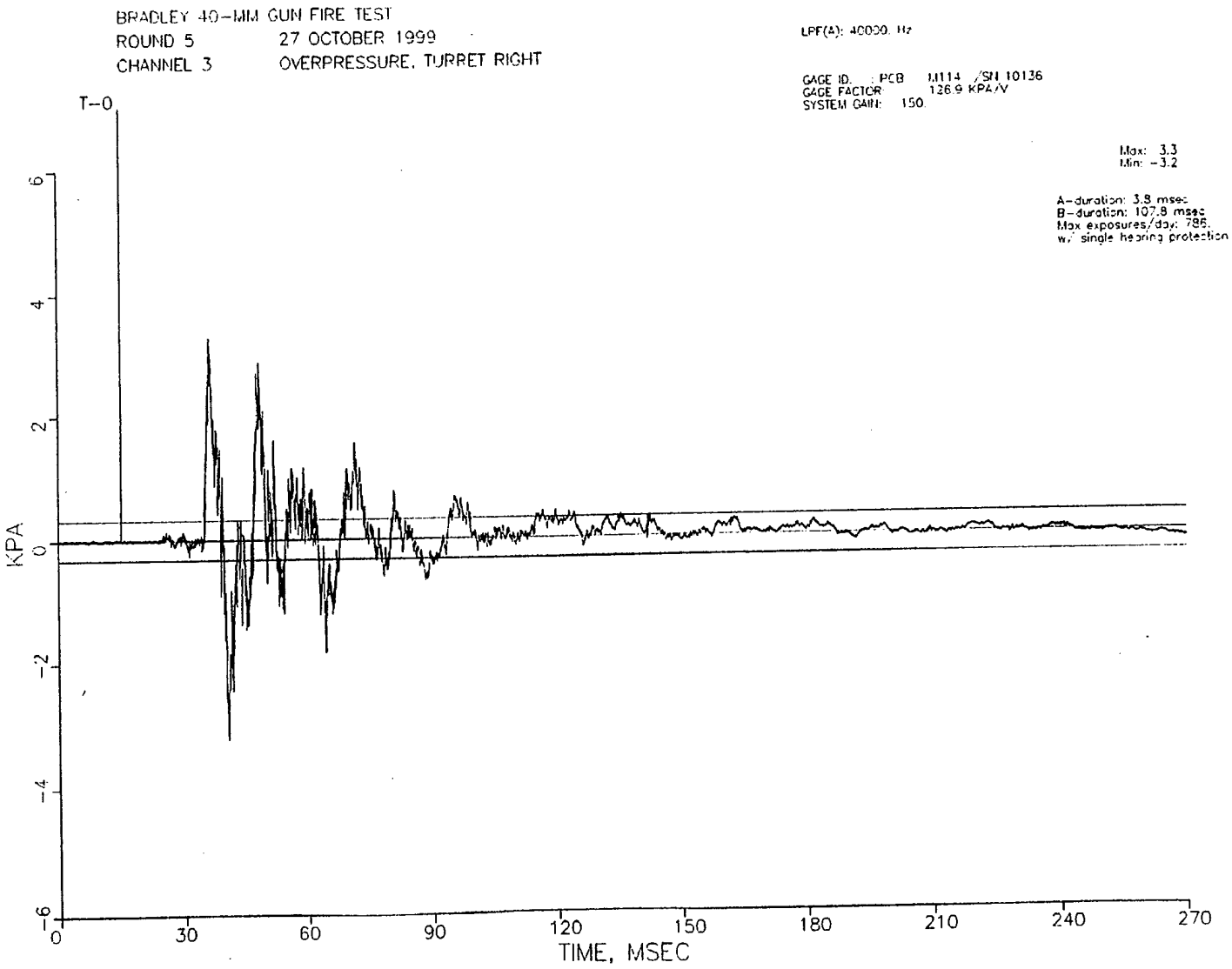

Figure B-19. Overpressure Plot for Shot 5 at the Turret Right Location

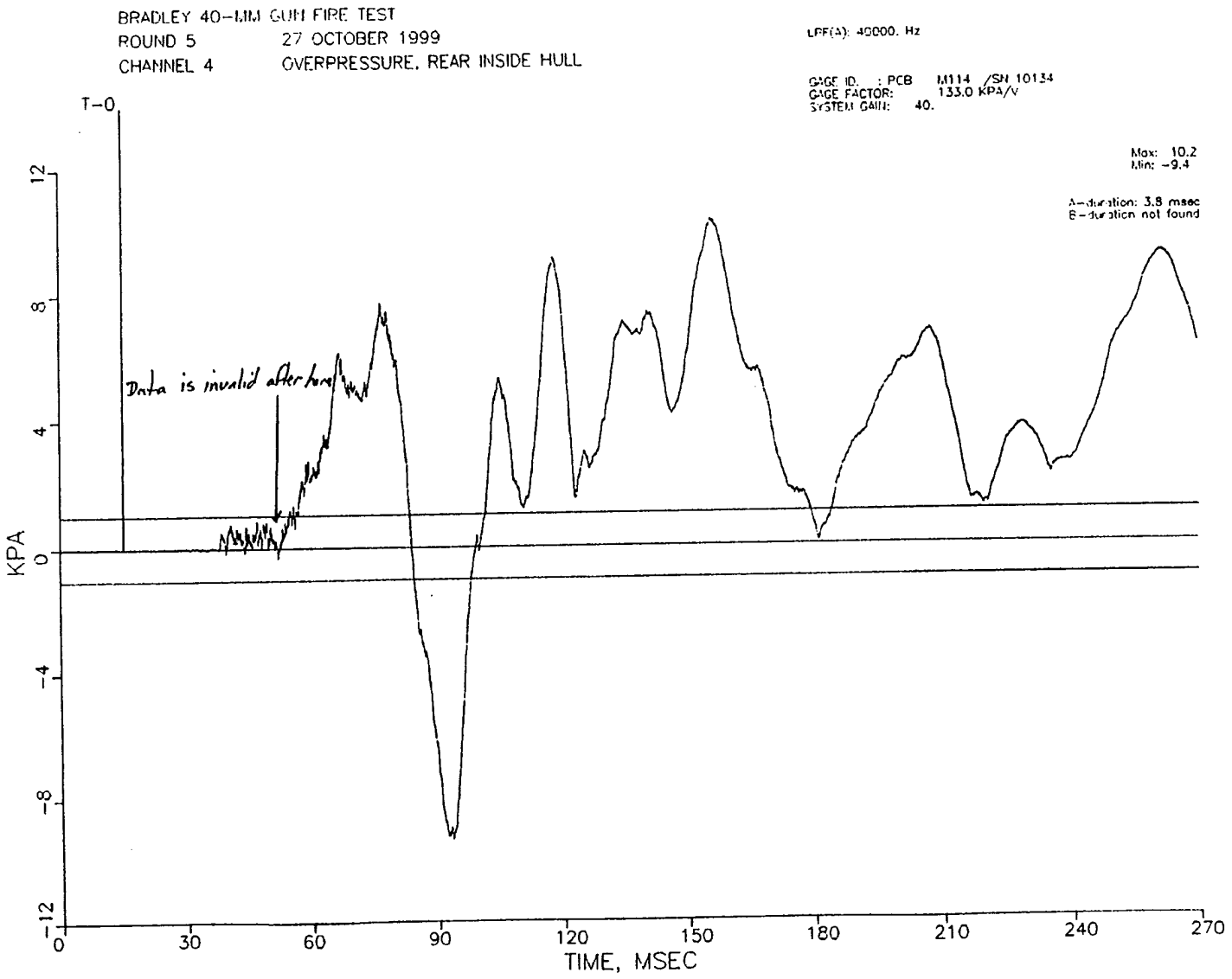

Figure B-20. Overpressure Plot for Shot 5 at the Rear Crew Area Location

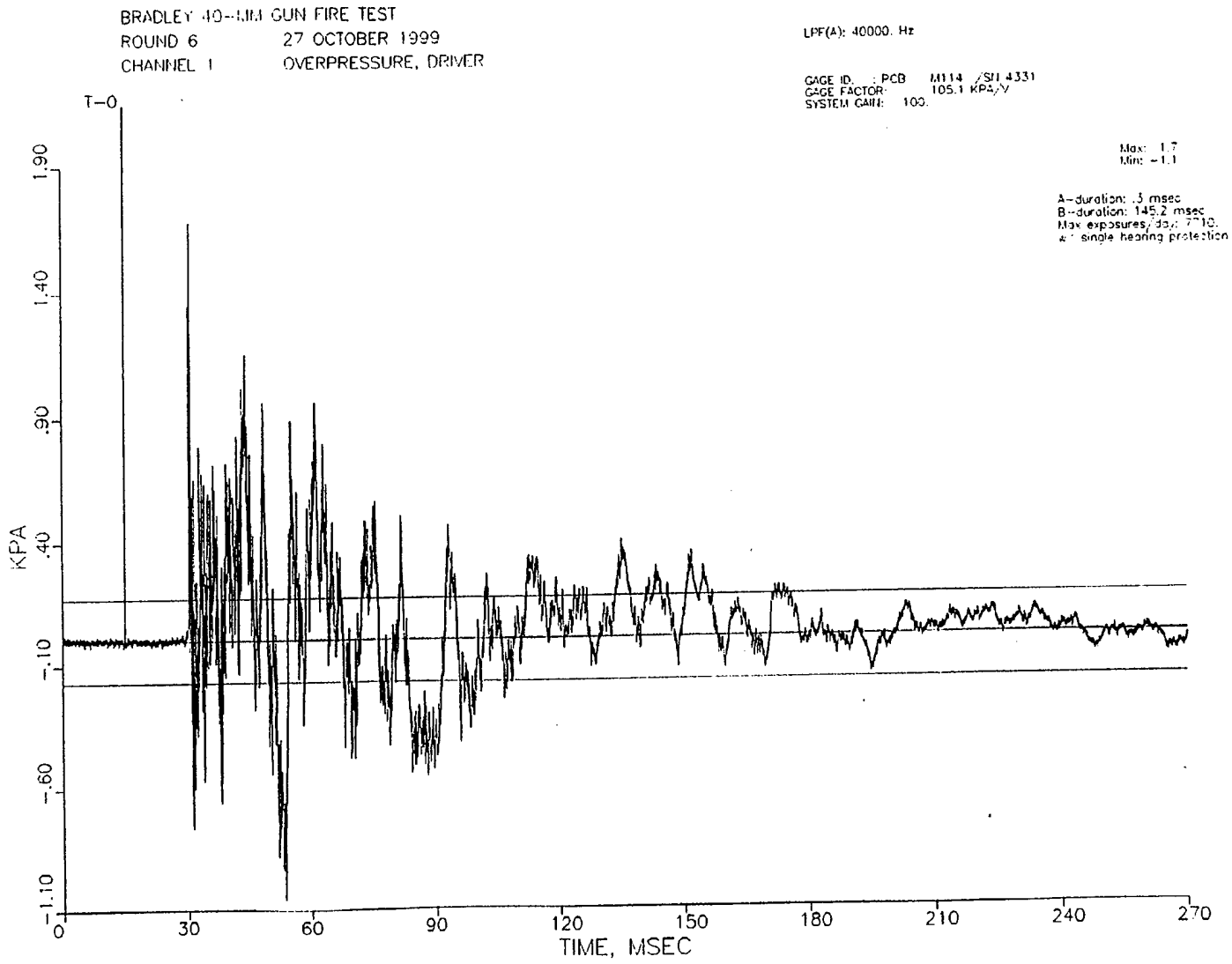

Figure B-21. Overpressure Plot for Shot 6 at the Driver Location

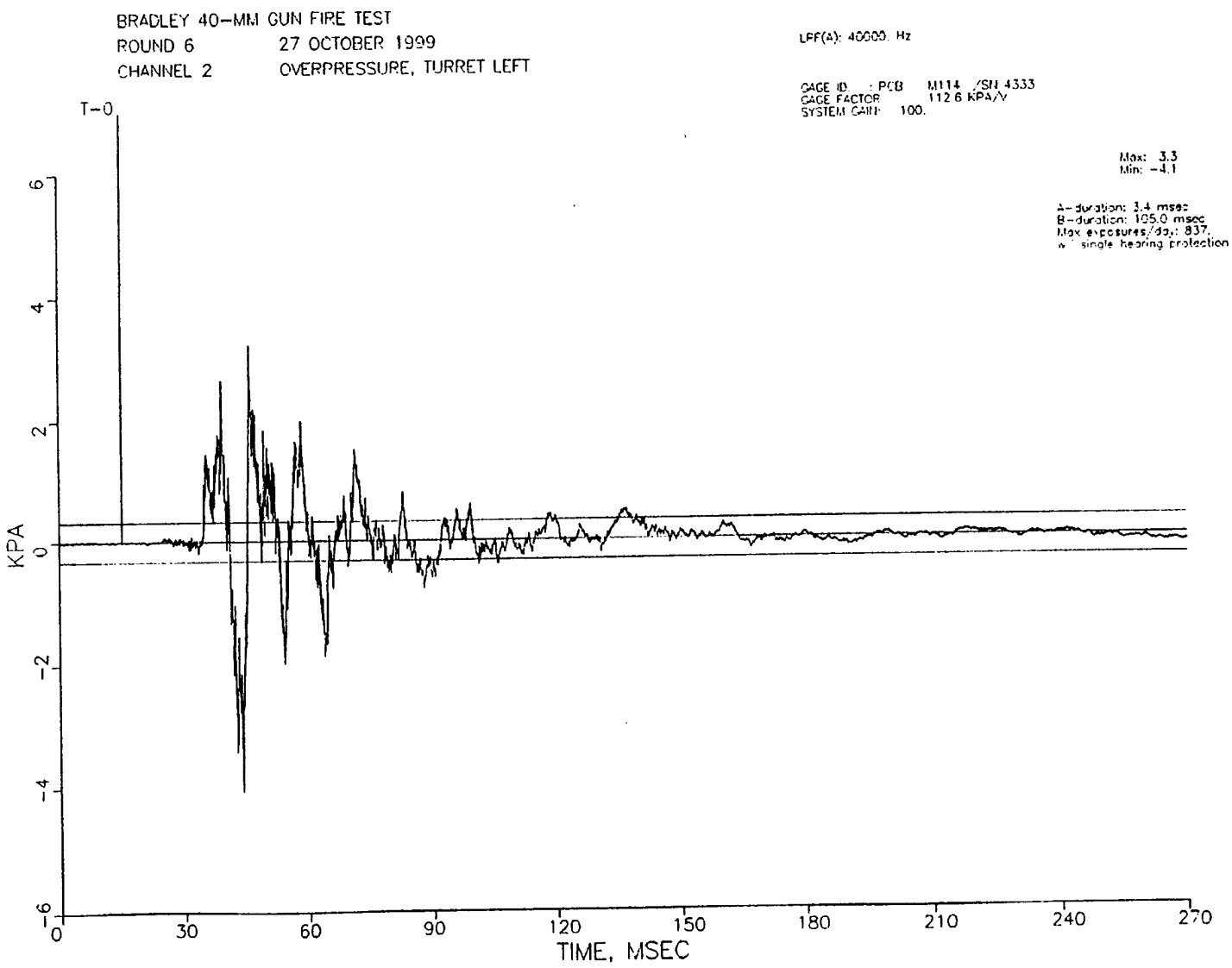

Figure B-22. Overpressure Plot for Shot 6 at the Turret Left Location

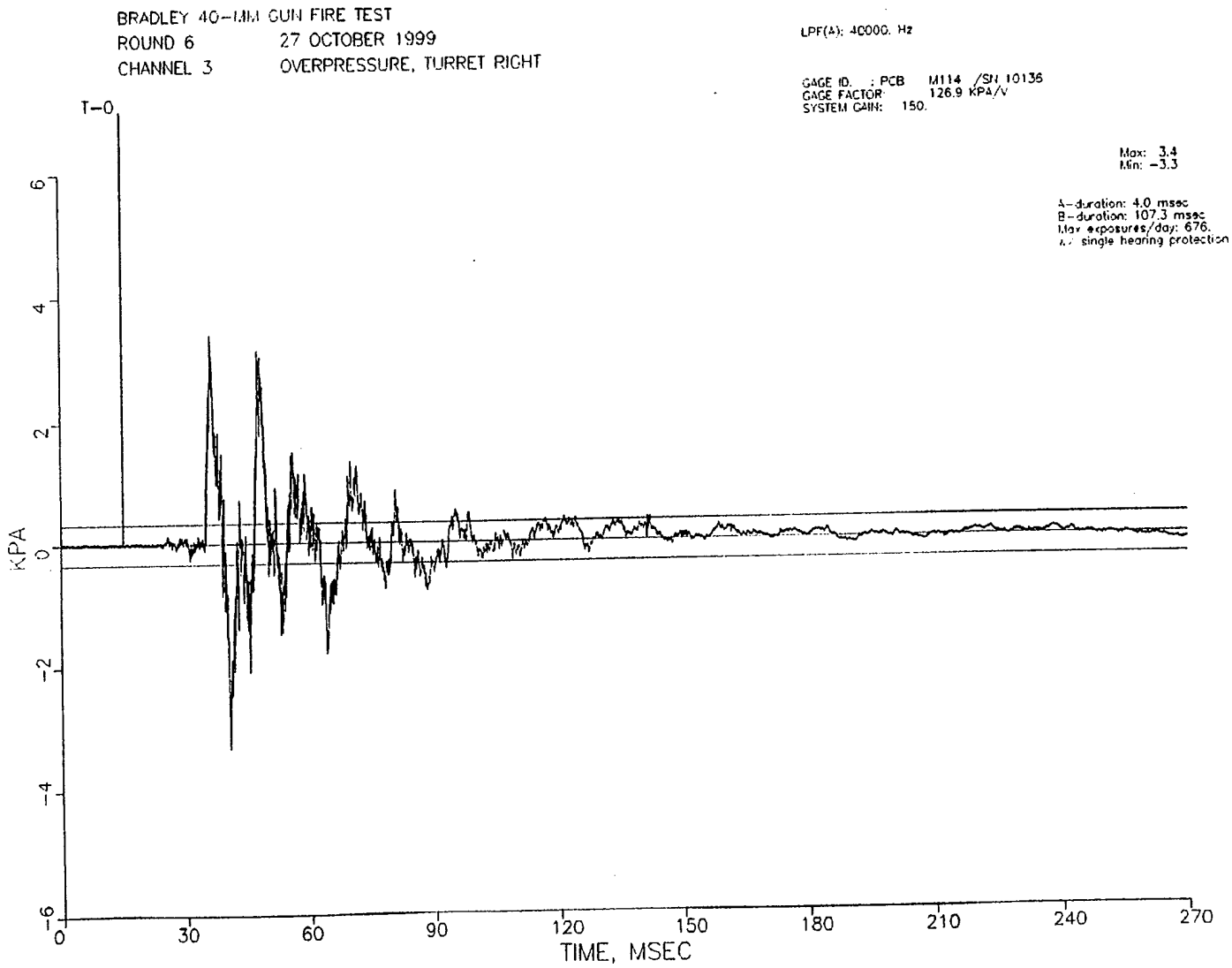

Figure B-23. Overpressure Plot for Shot 6 at the Turret Right Location

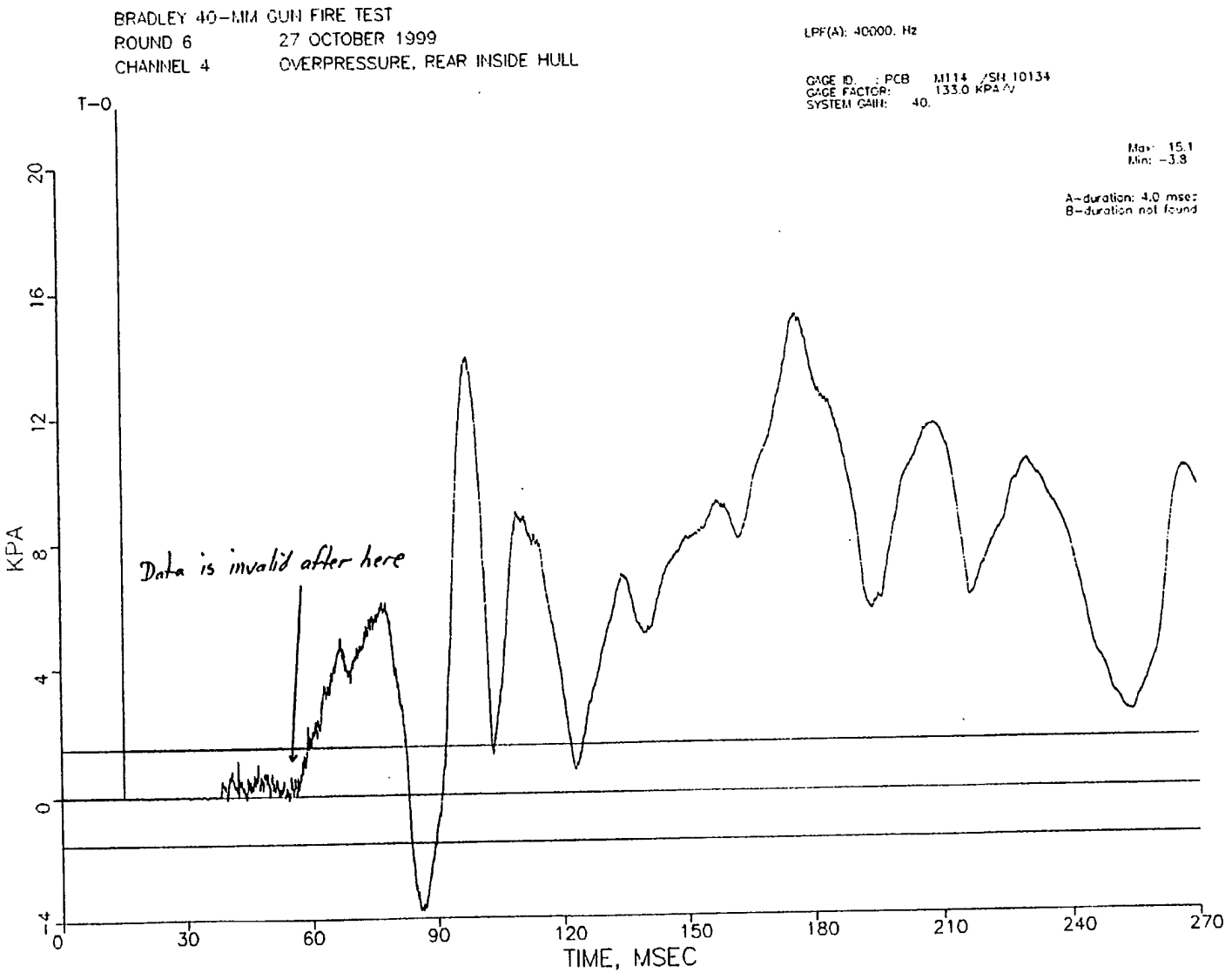

Figure B-24. Overpressure Plot for Shot 6 at the Rear Crew Area Location

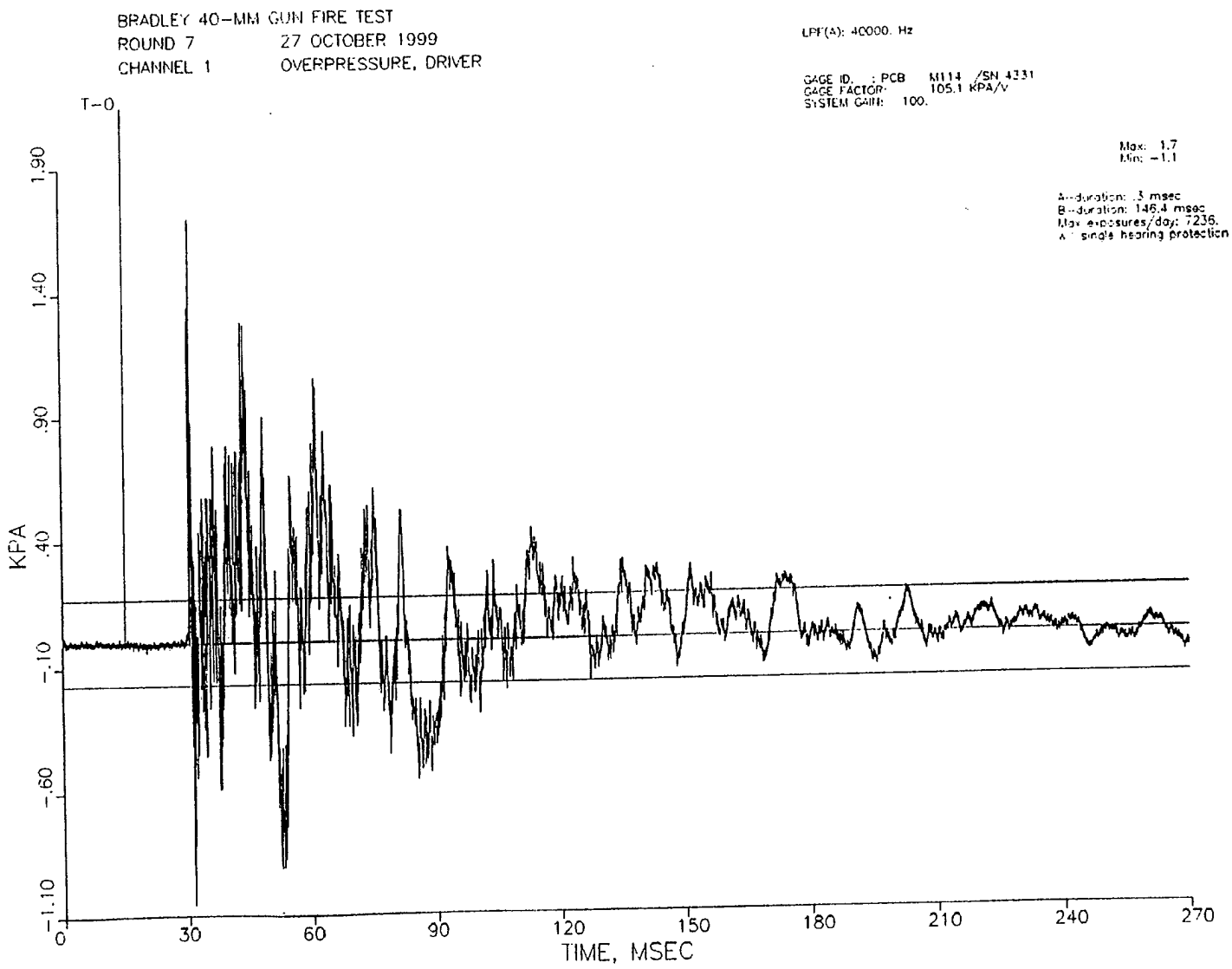

Figure B-25. Overpressure Plot for Shot 7 at the Driver Location

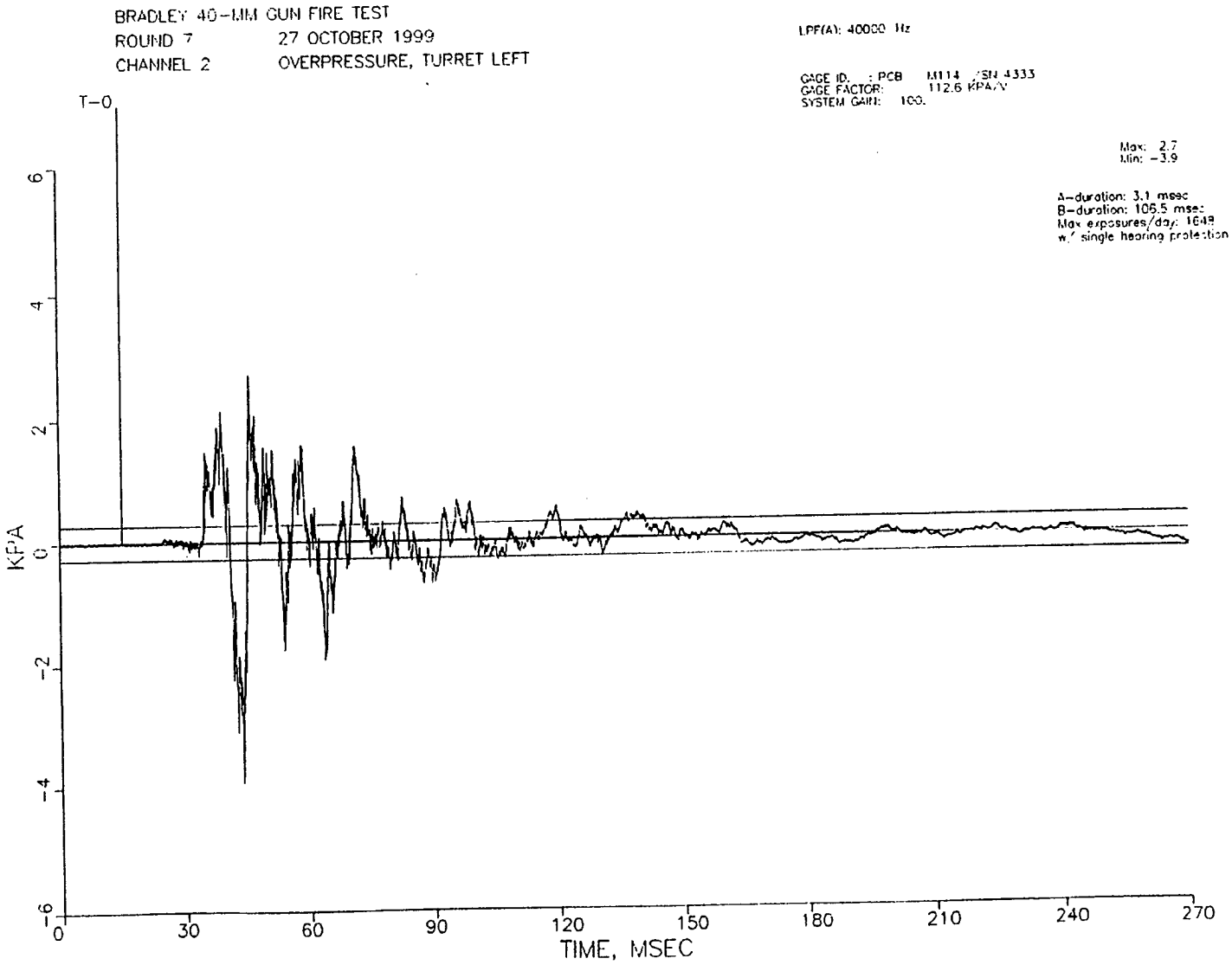

Figure B-26. Overpressure Plot for Shot 7 at the Turret Left Location

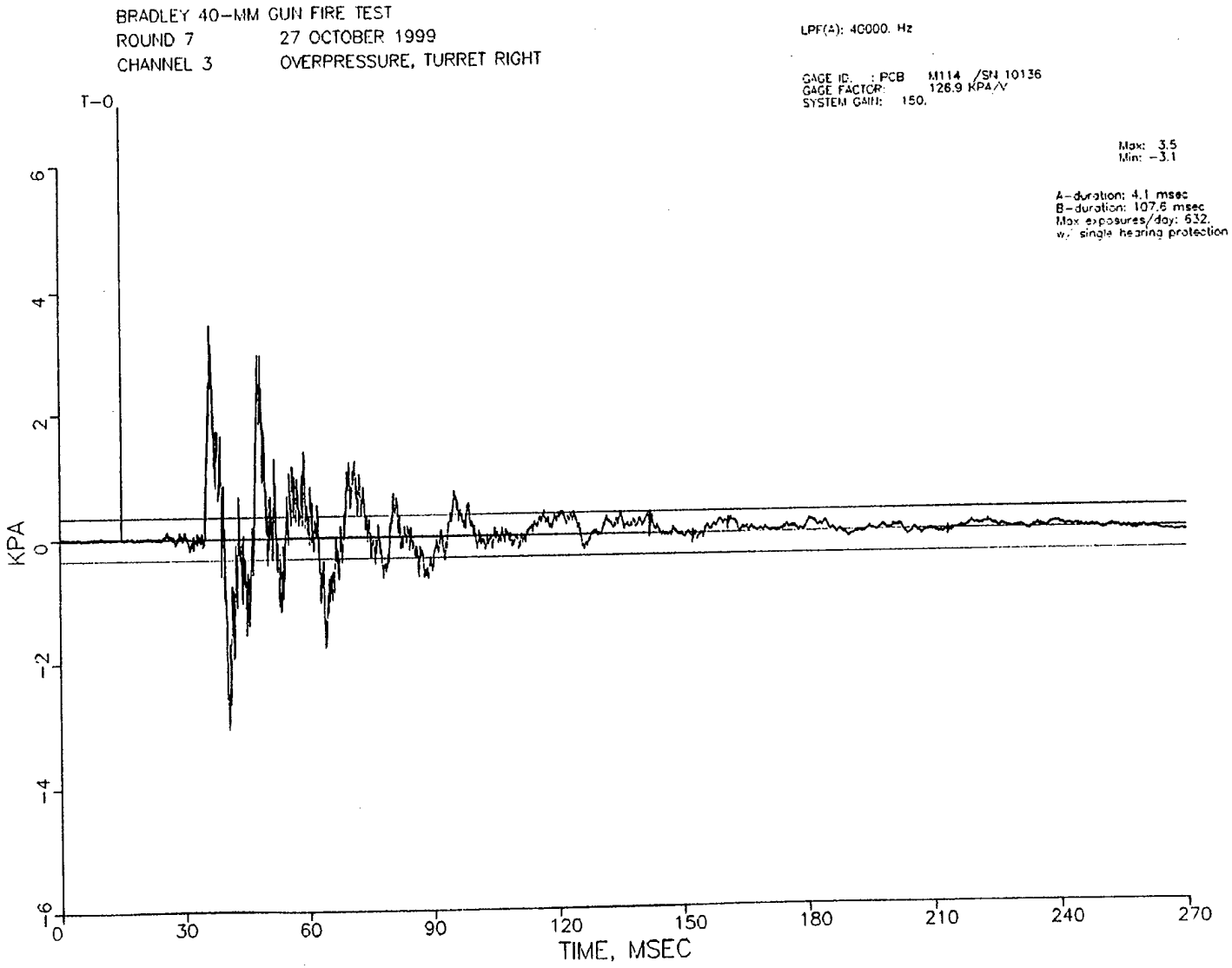

Figure B-27. Overpressure Plot for Shot 7 at the Turret Right Location

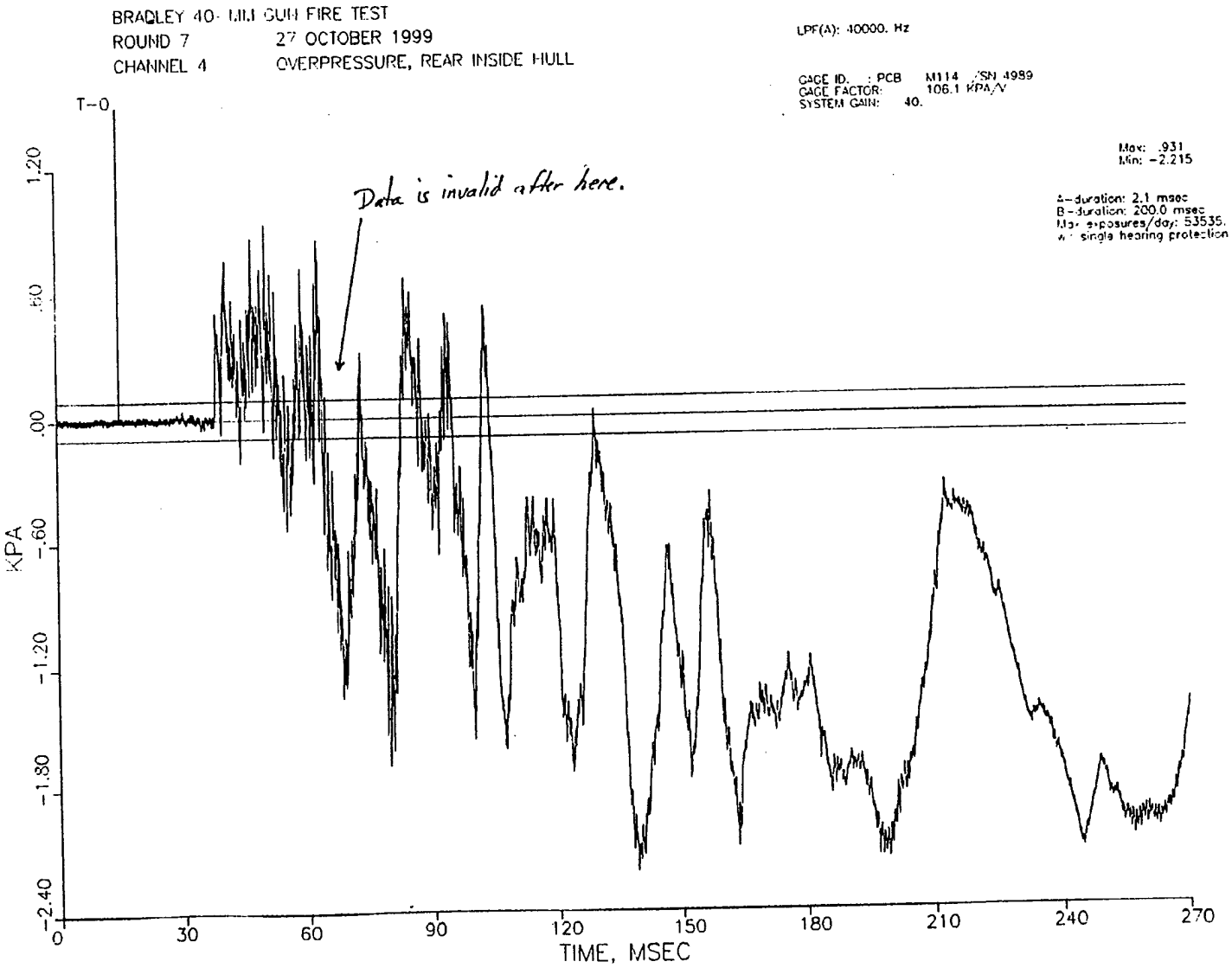

Figure B-28. Overpressure Plot for Shot 7 at the Rear Crew Area Location

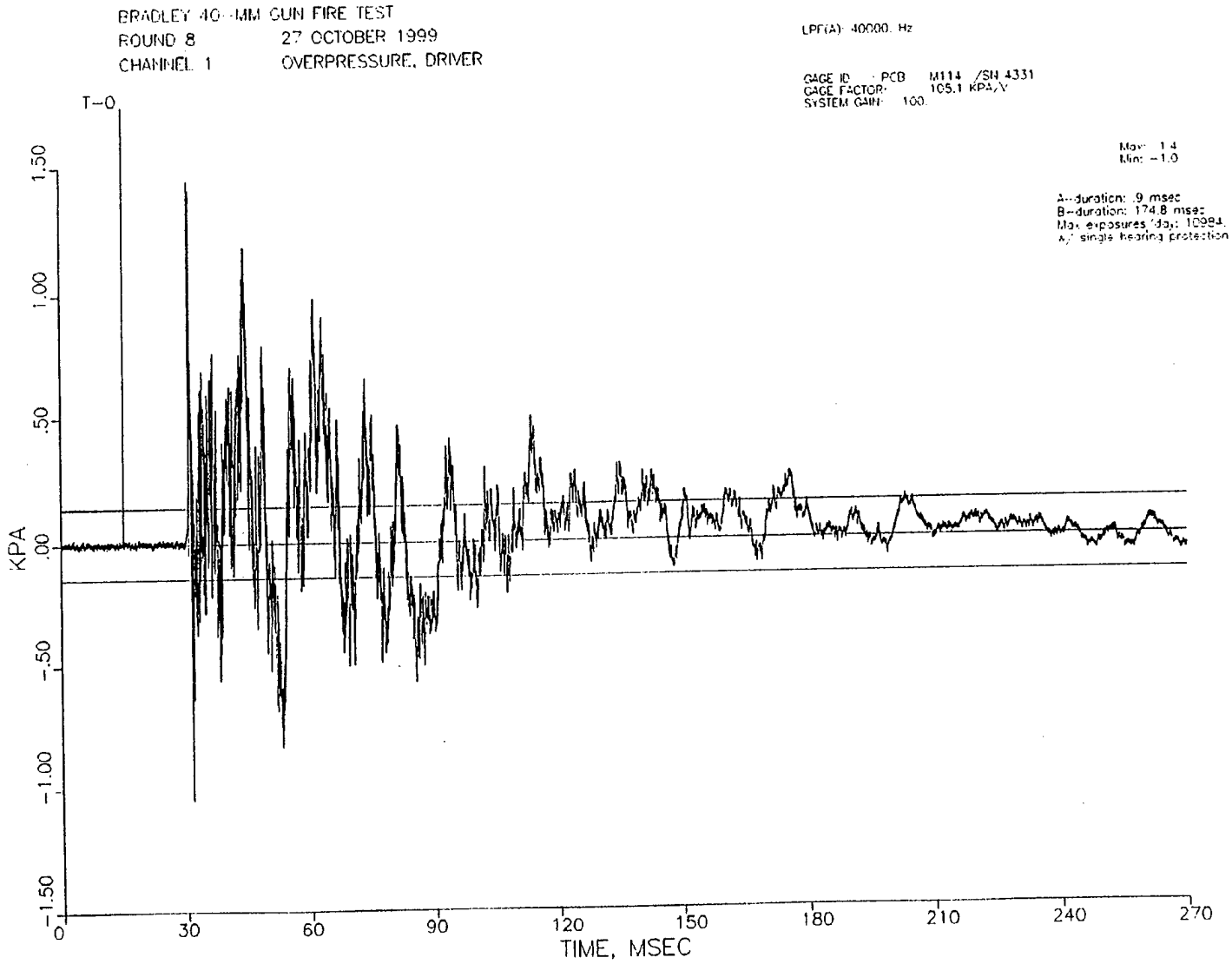

Figure B-29. Overpressure Plot for Shot 8 at the Driver Location

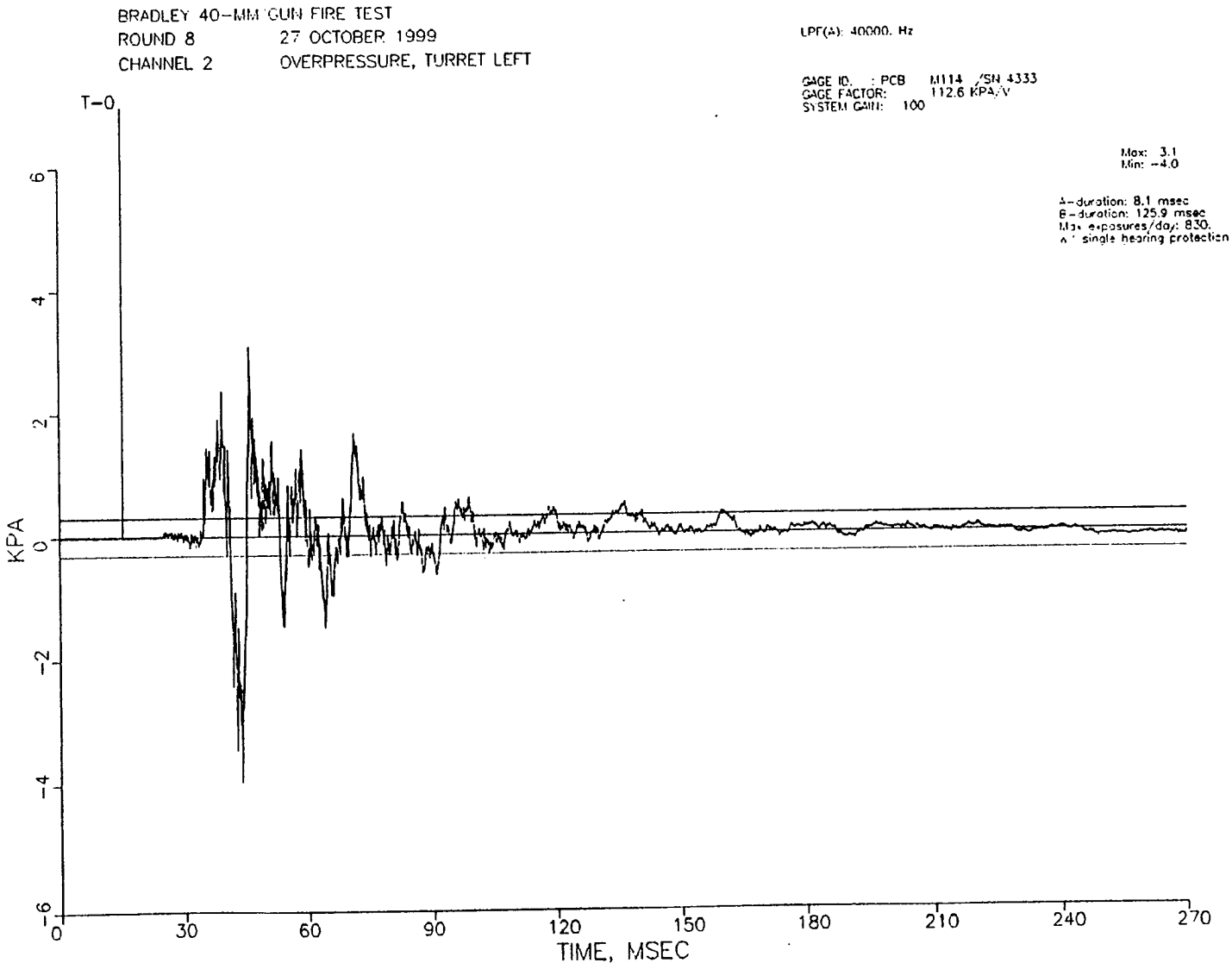

Figure B-30. Overpressure Plot for Shot 8 at the Turret Left Location

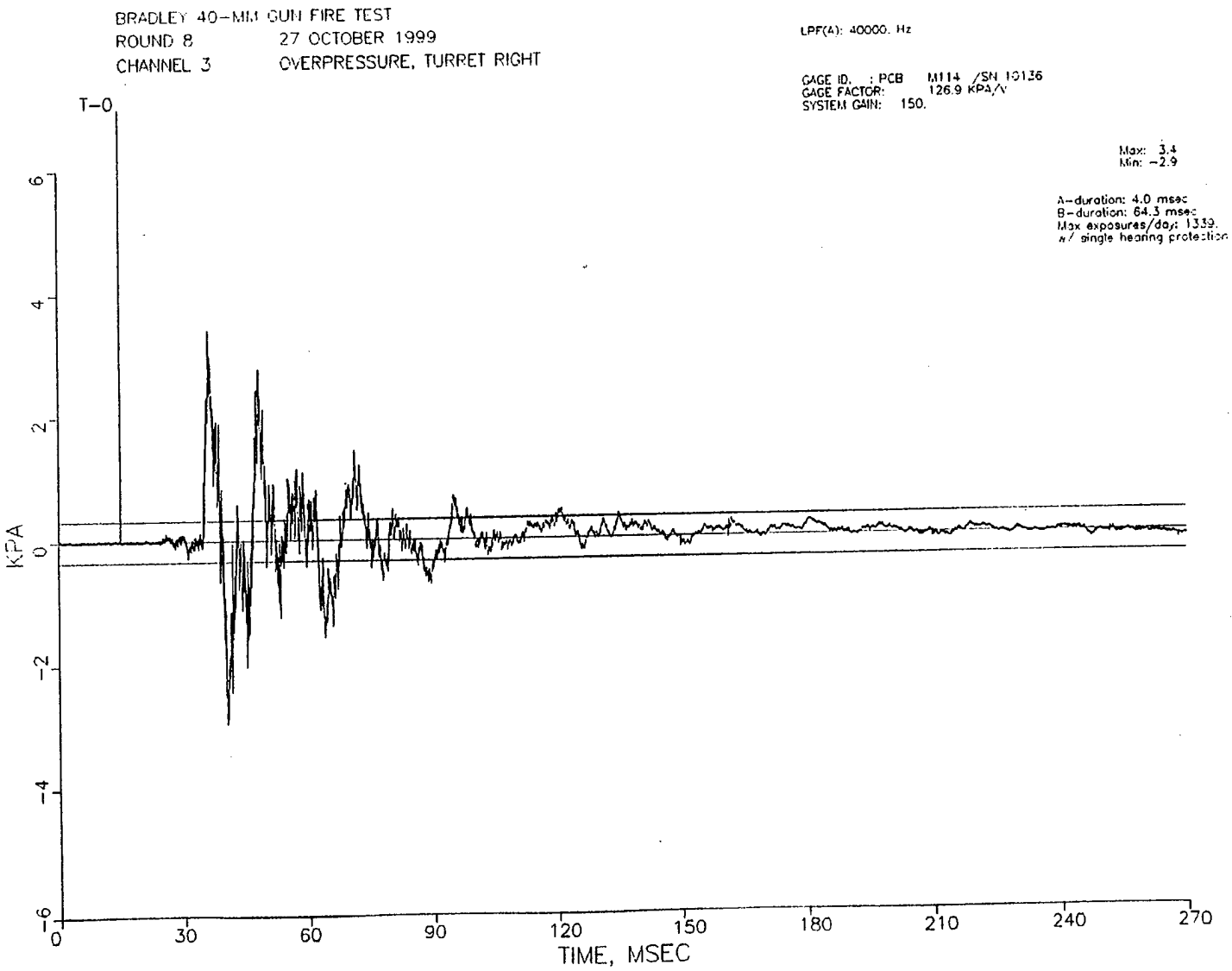

Figure B-31. Overpressure Plot for Shot 8 at the Turret Right Location

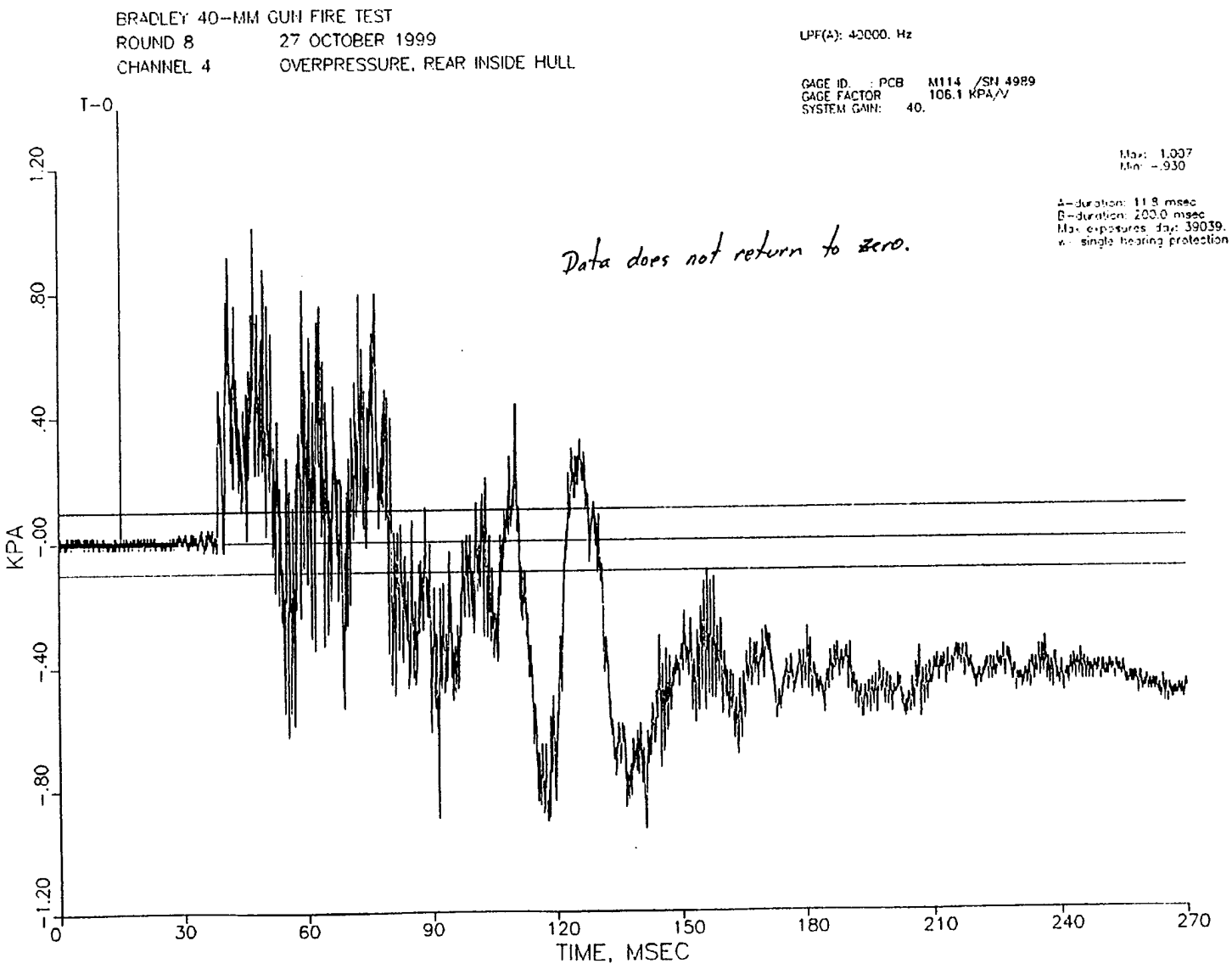

Figure B-32. Overpressure Plot for Shot 8 at the Rear Crew Area Location

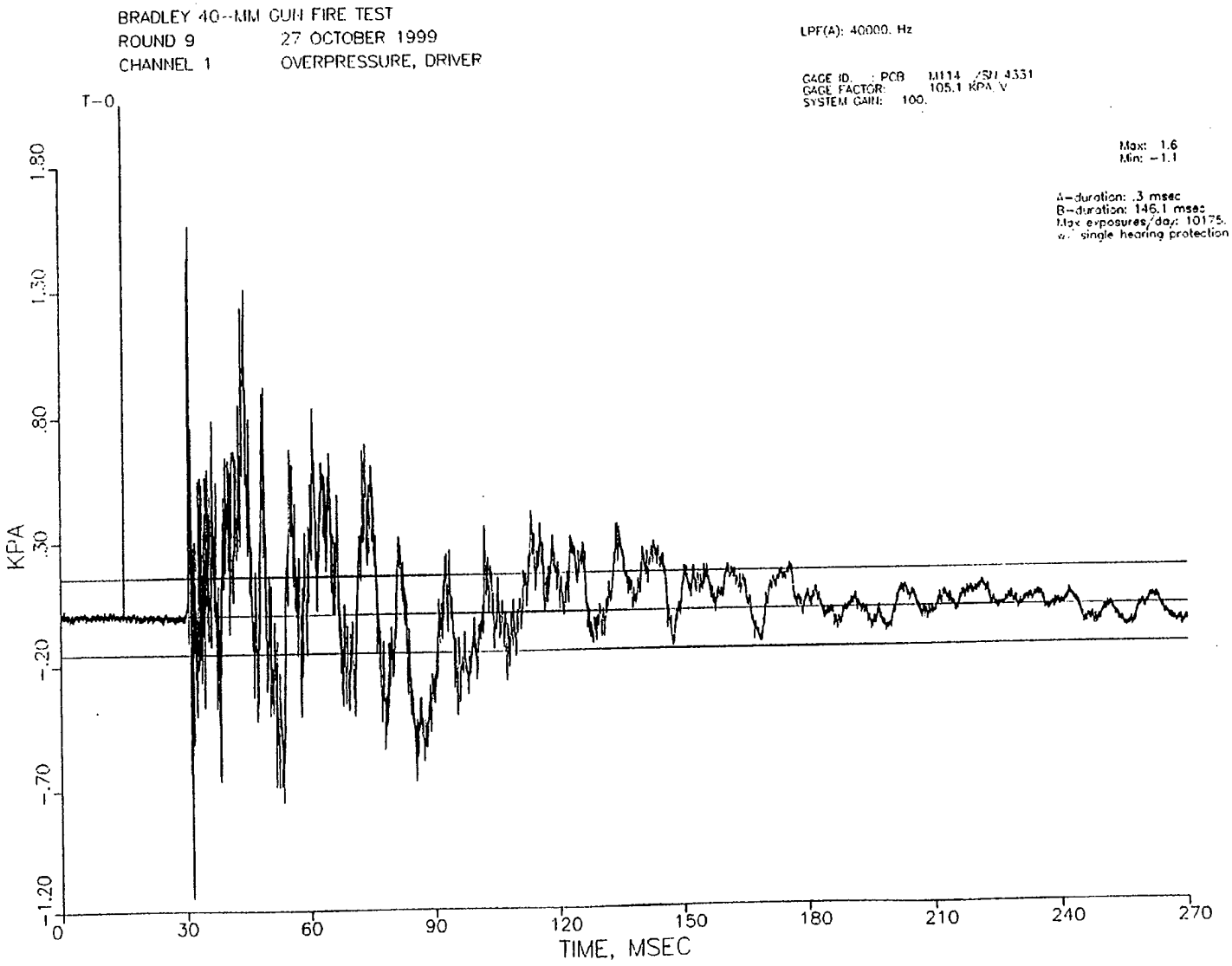

Figure B-33. Overpressure Plot for Shot 9 at the Driver Location

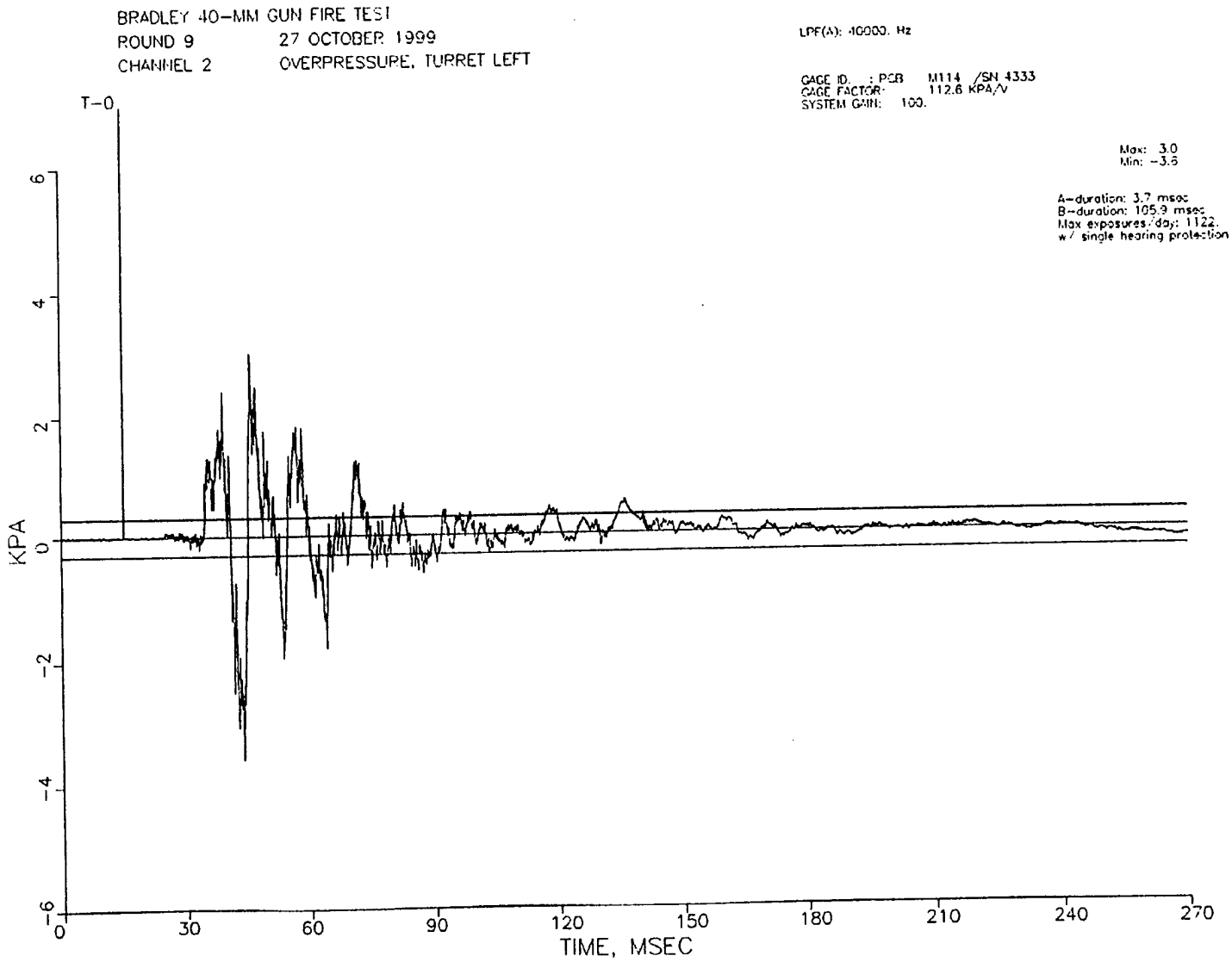

Figure B-34. Overpressure Plot for Shot 9 at the Turret Left Location

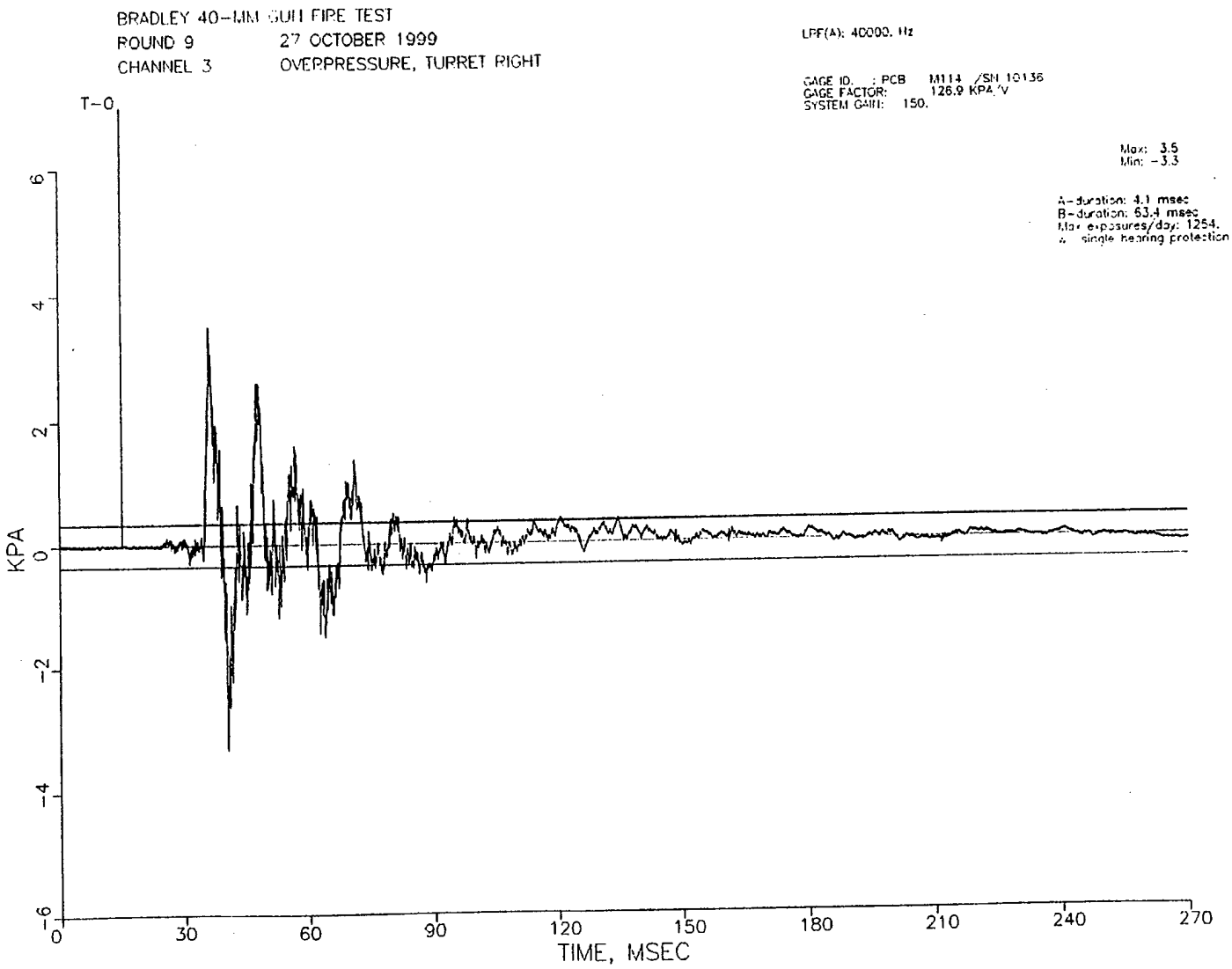

Figure B-35. Overpressure Plot for Shot 9 at the Turret Right Location

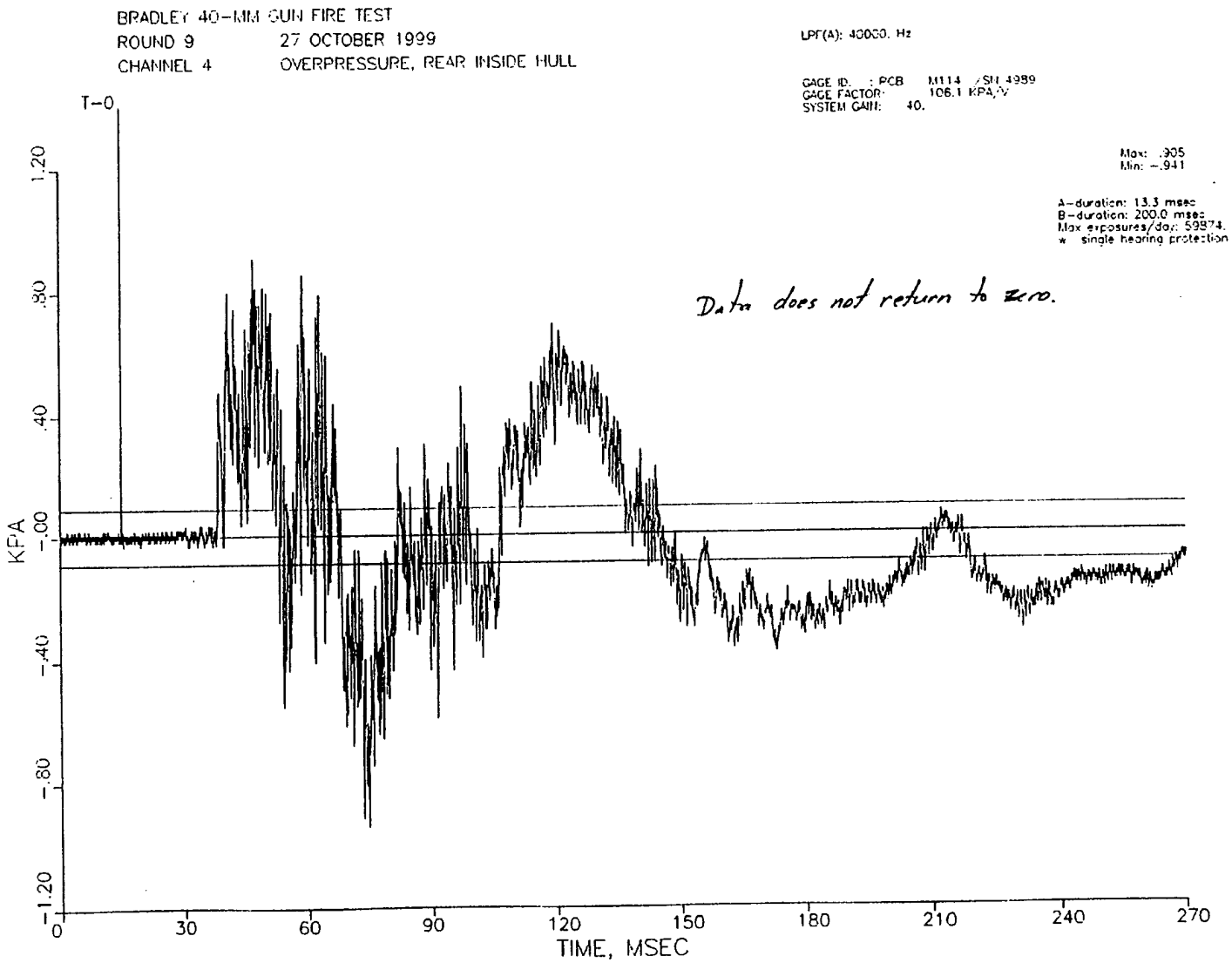

Figure B-36. Overpressure Plot for Shot 9 at the Rear Crew Area Location

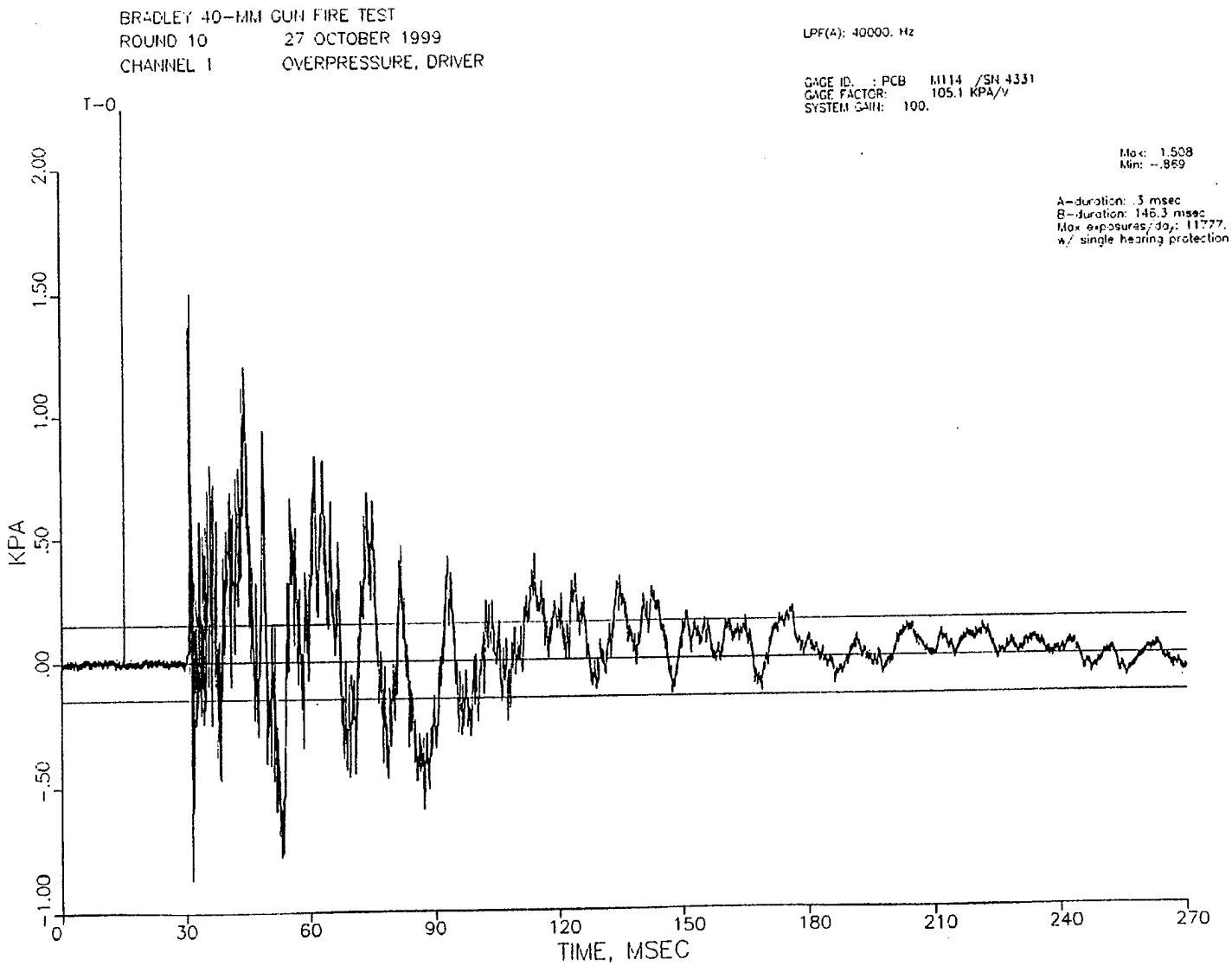

Figure B-37. Overpressure Plot for Shot 10 at the Driver Location

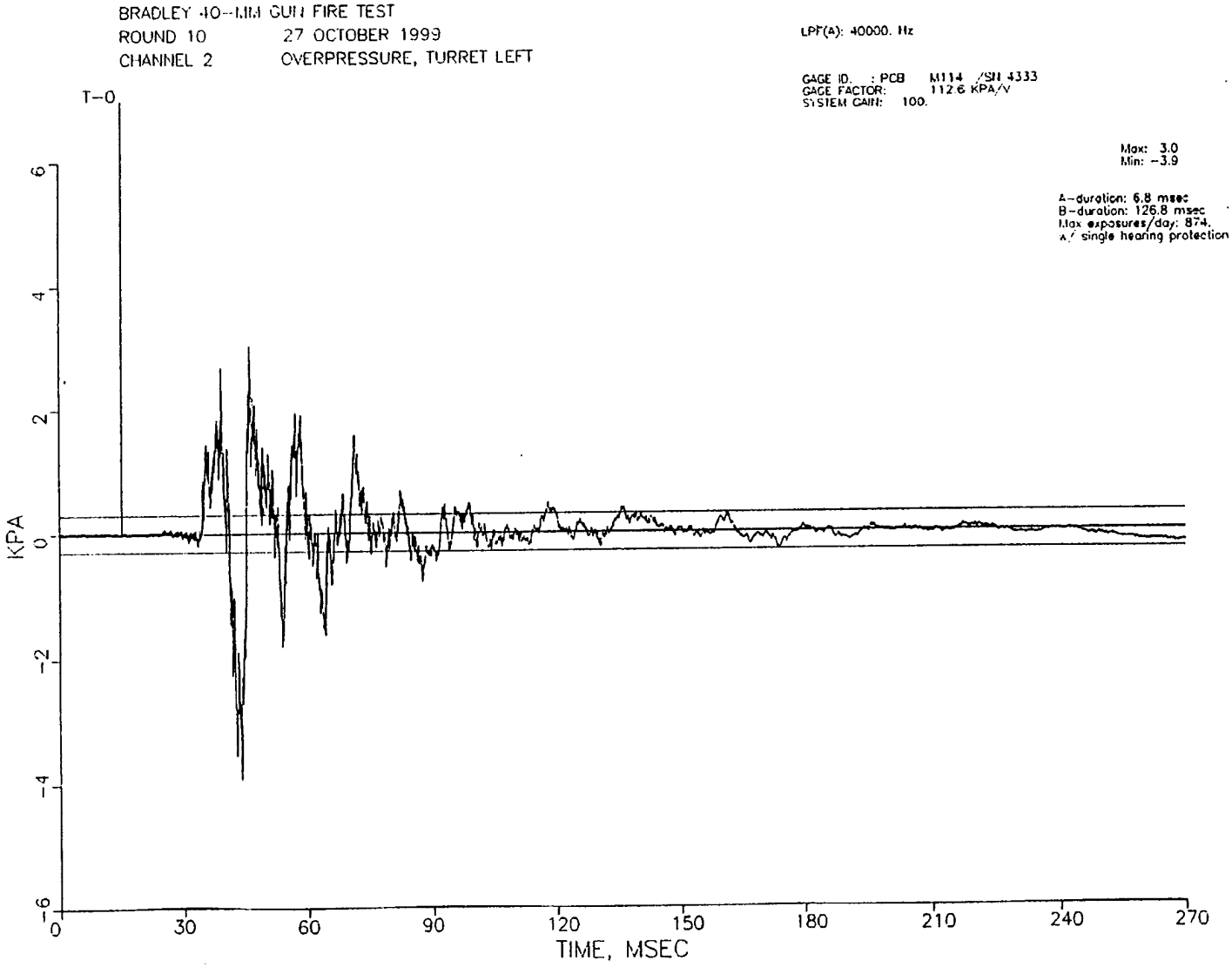

Figure B-38. Overpressure Plot for Shot 10 at the Turret Left Location

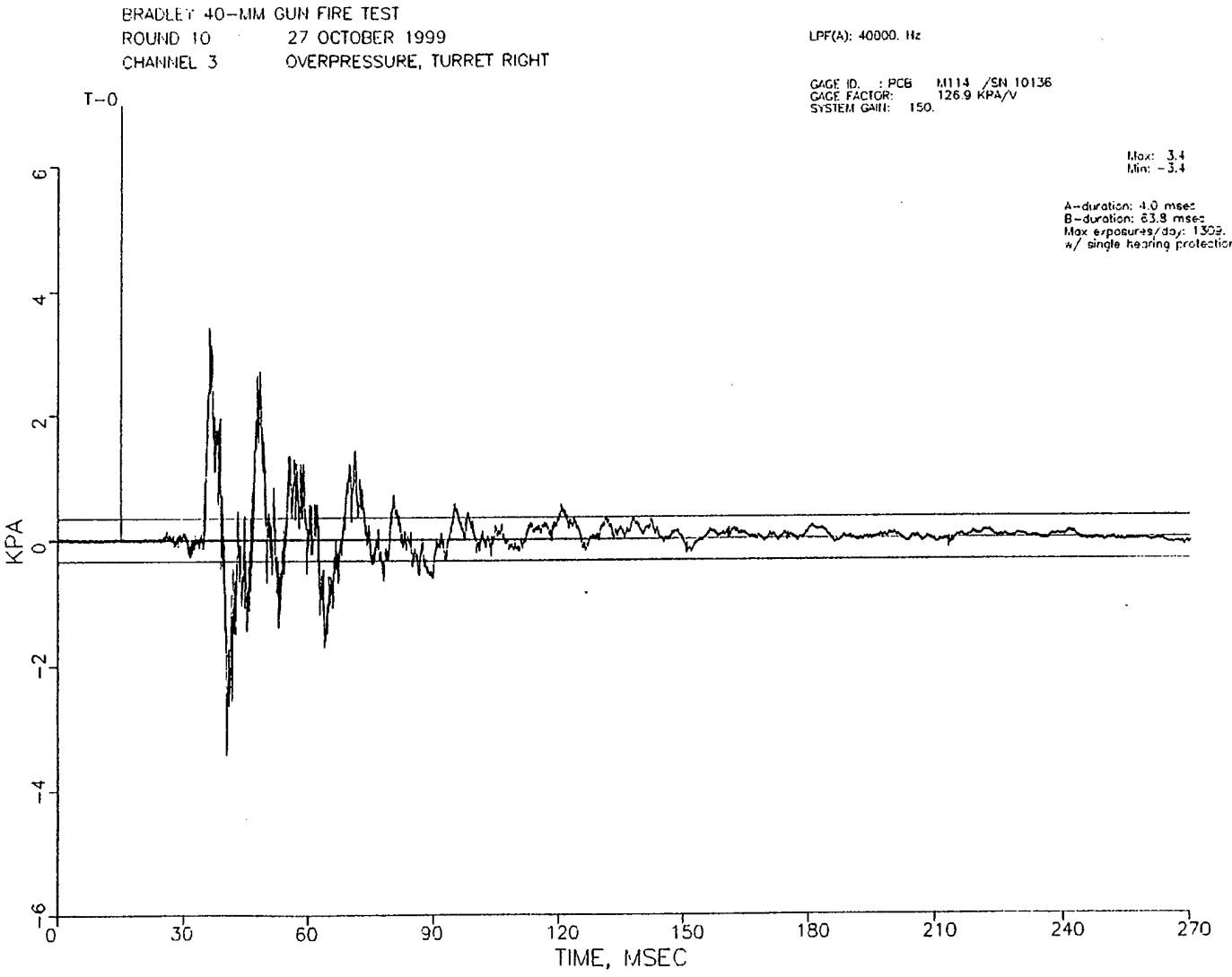

Figure B-39. Overpressure Plot for Shot 10 at the Turret Right Location

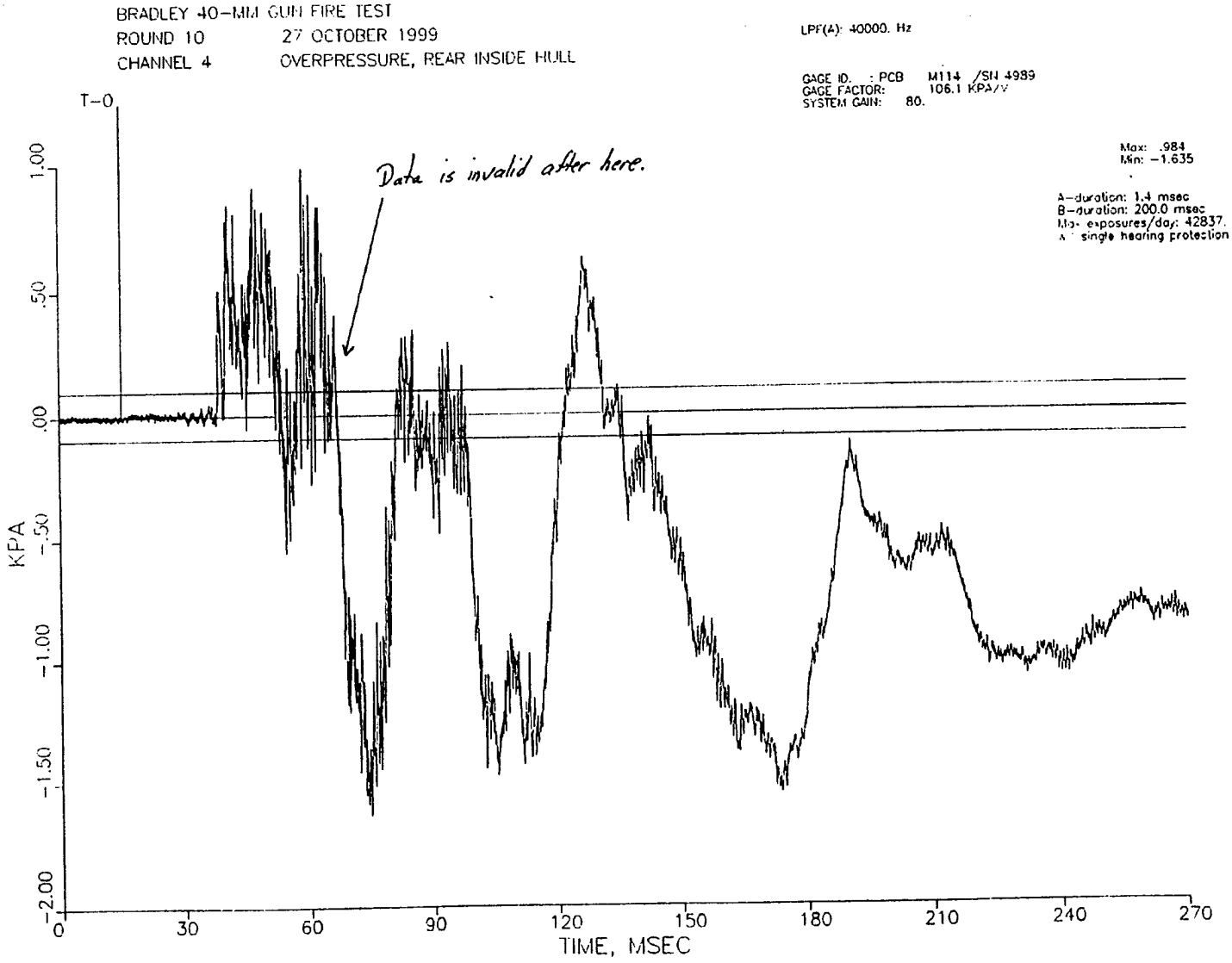

Figure B-40. Overpressure Plot for Shot 10 at the Rear Crew Area Location

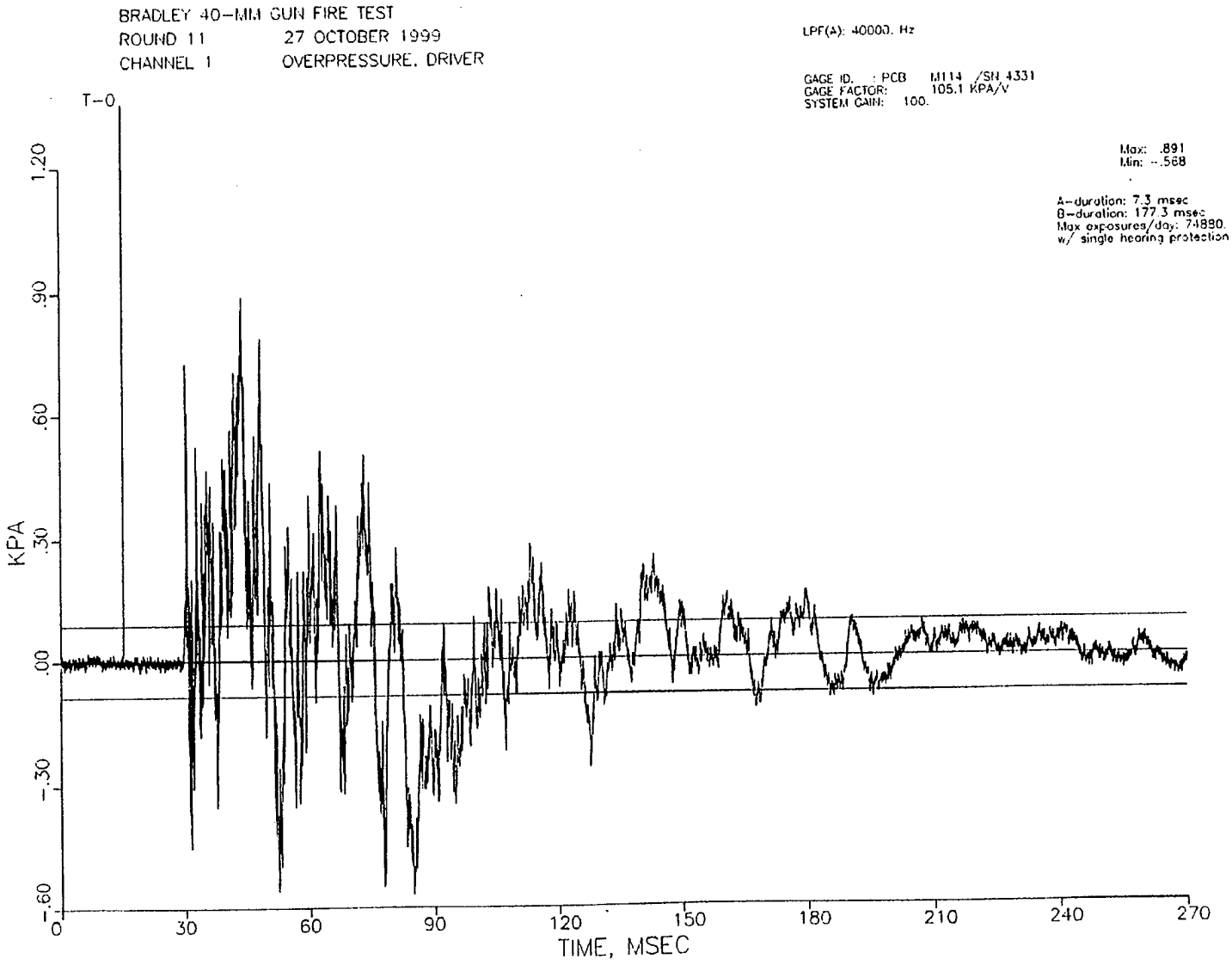

Figure B-41. Overpressure Plot for Shot 11 at the Driver Location

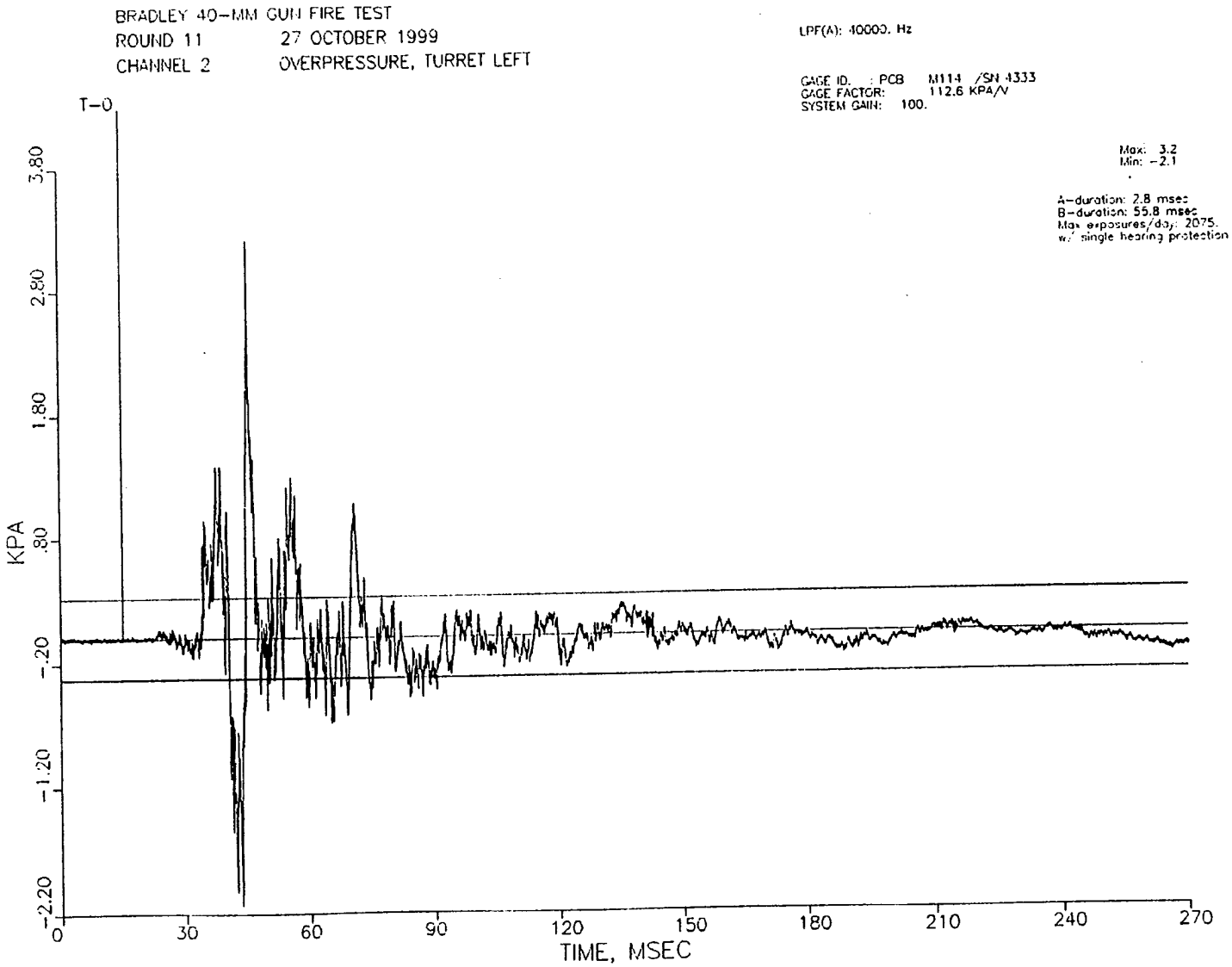

Figure B-42. Overpressure Plot for Shot 11 at the Turret Left Location

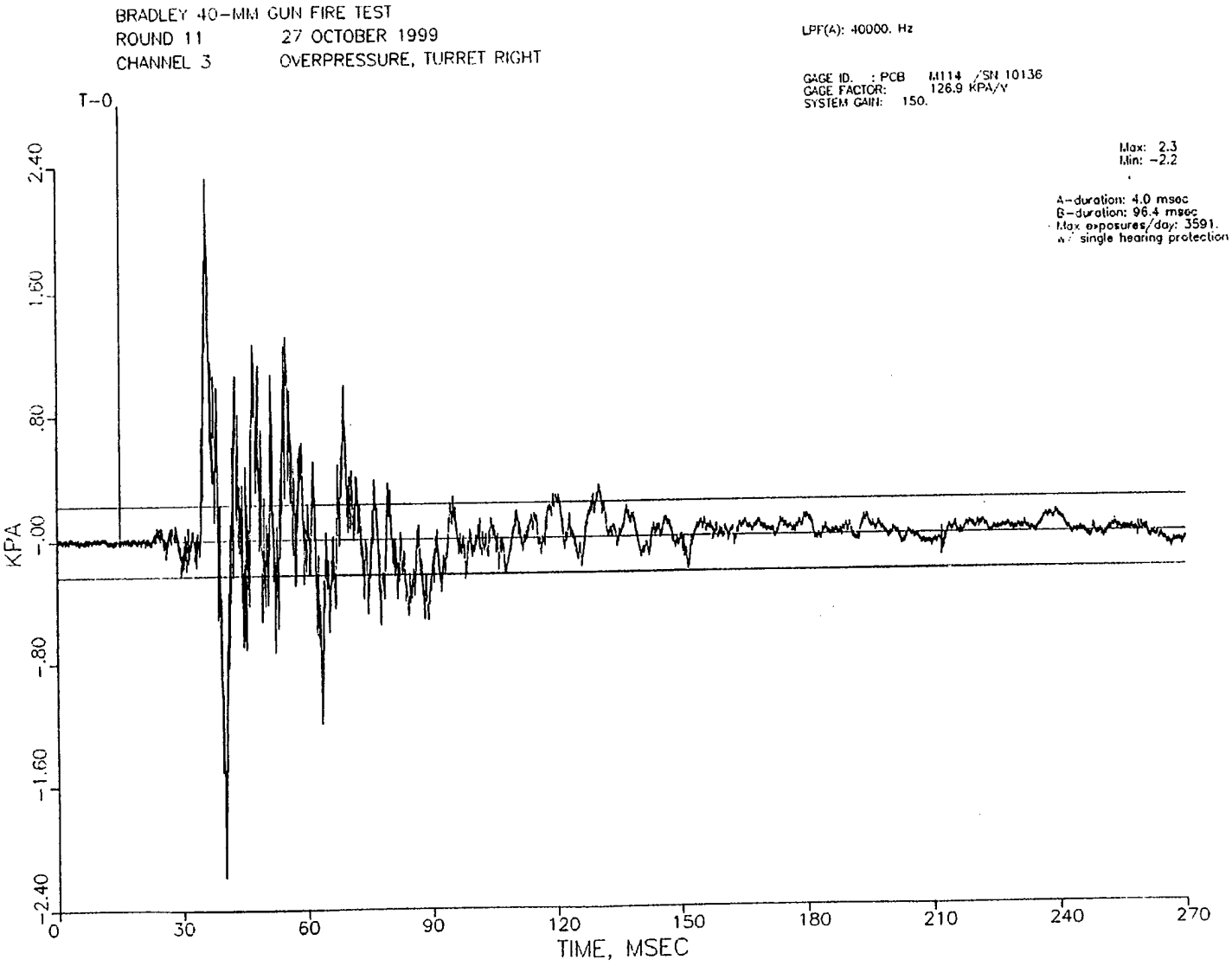

Figure B-43. Overpressure Plot for Shot 11 at the Turret Right Location

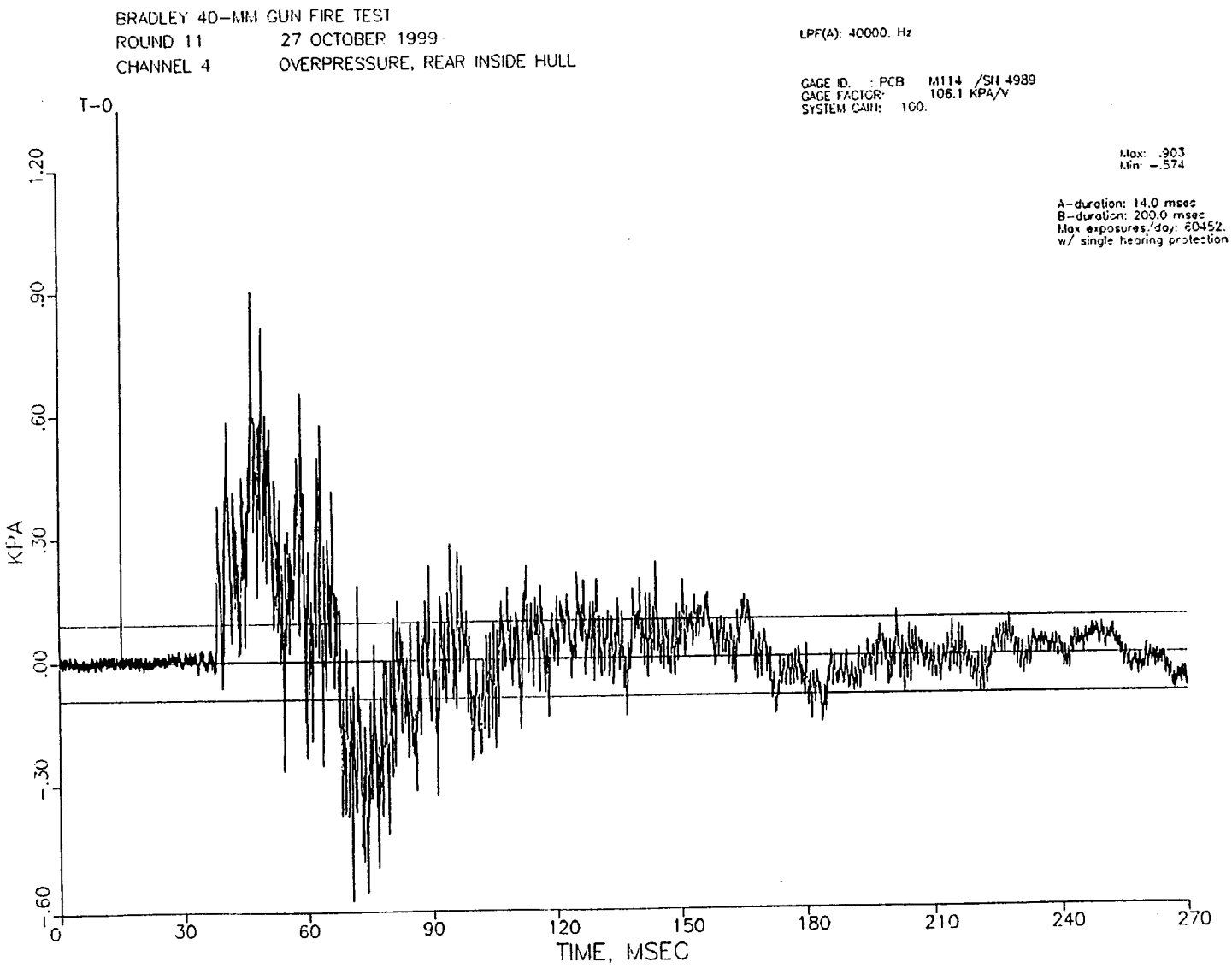

Figure B-44. Overpressure Plot for Shot 11 at the Rear Crew Area Location

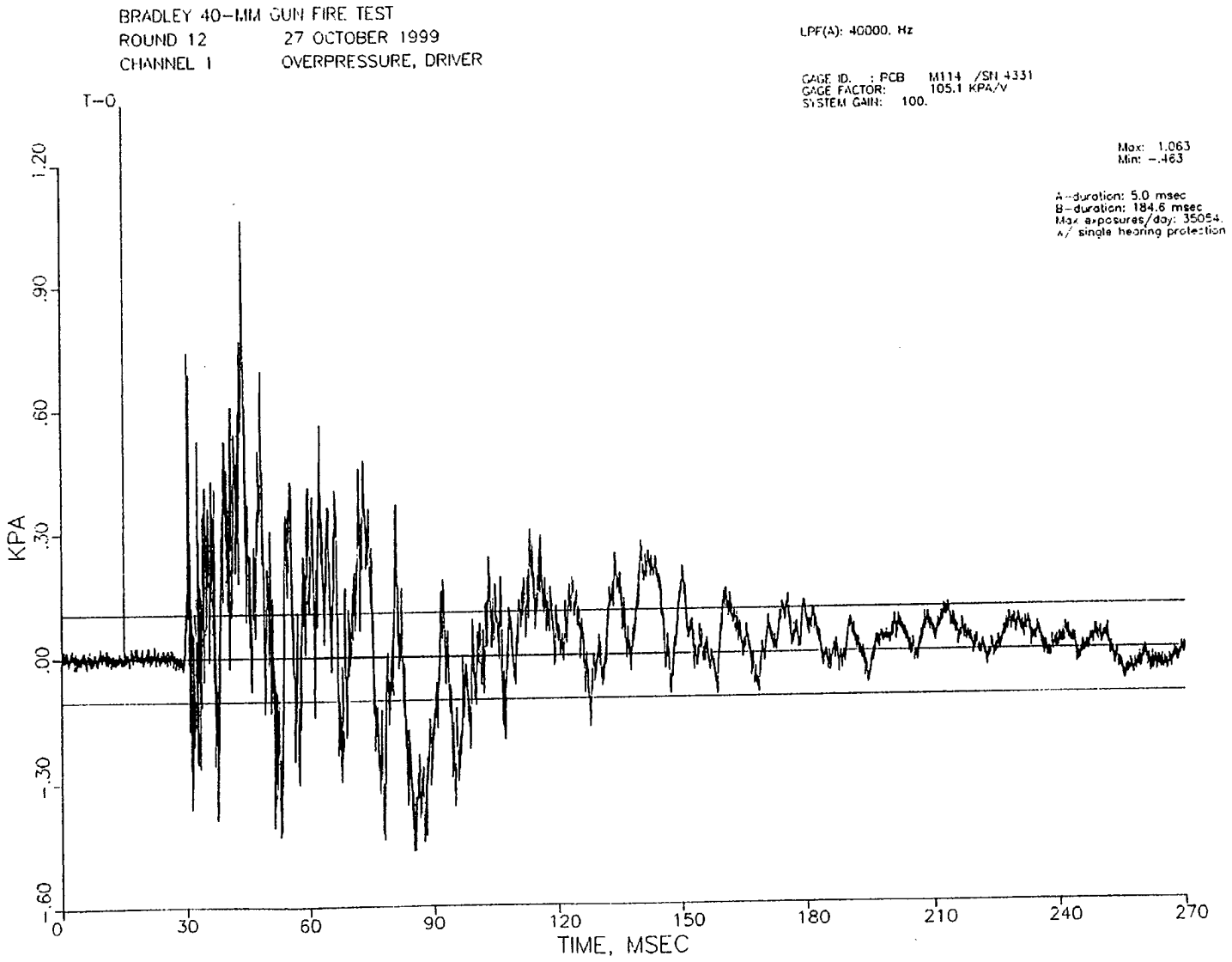

Figure B-45. Overpressure Plot for Shot 12 at the Driver Location

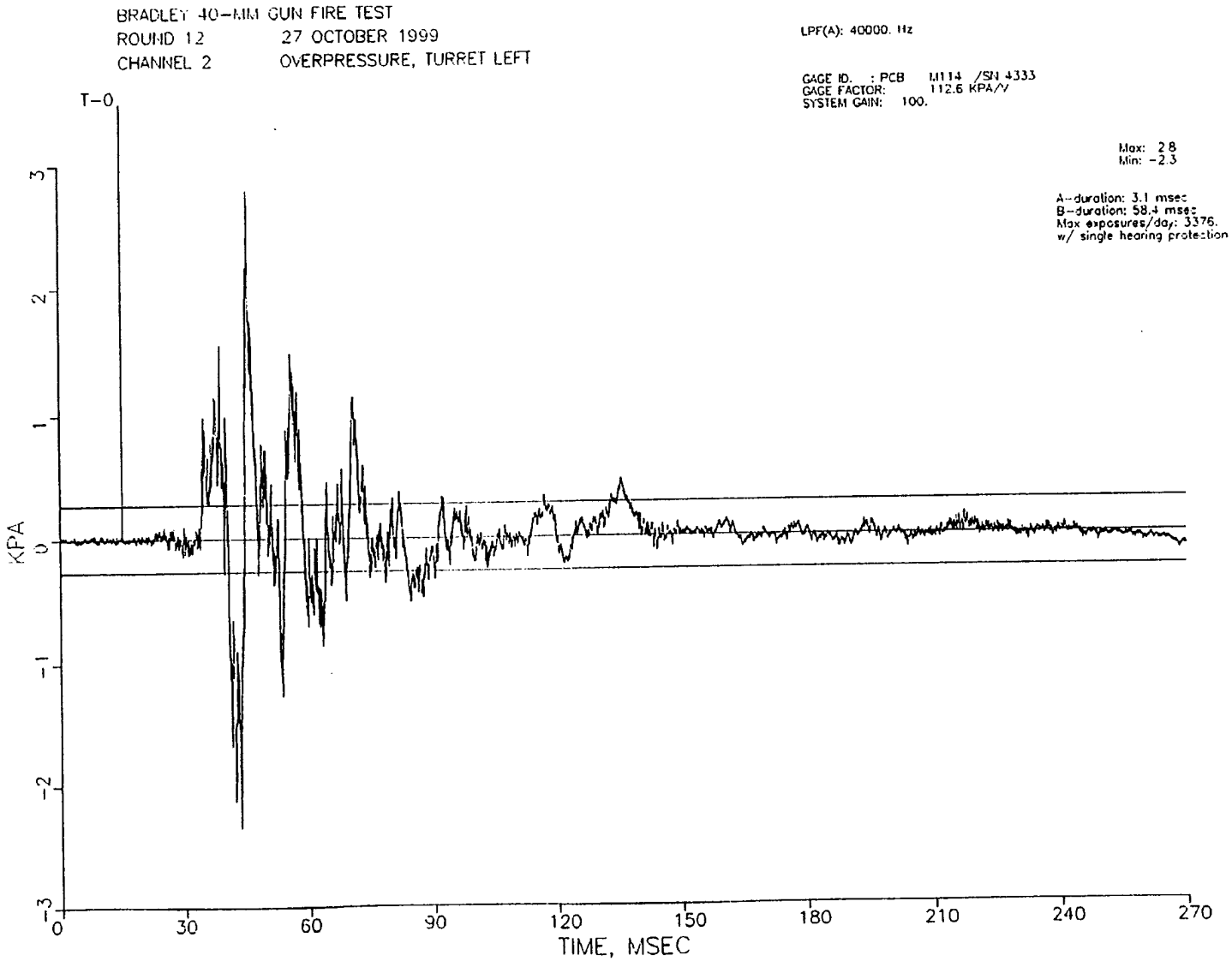

Figure B-46. Overpressure Plot for Shot 12 at the Turret Left Location

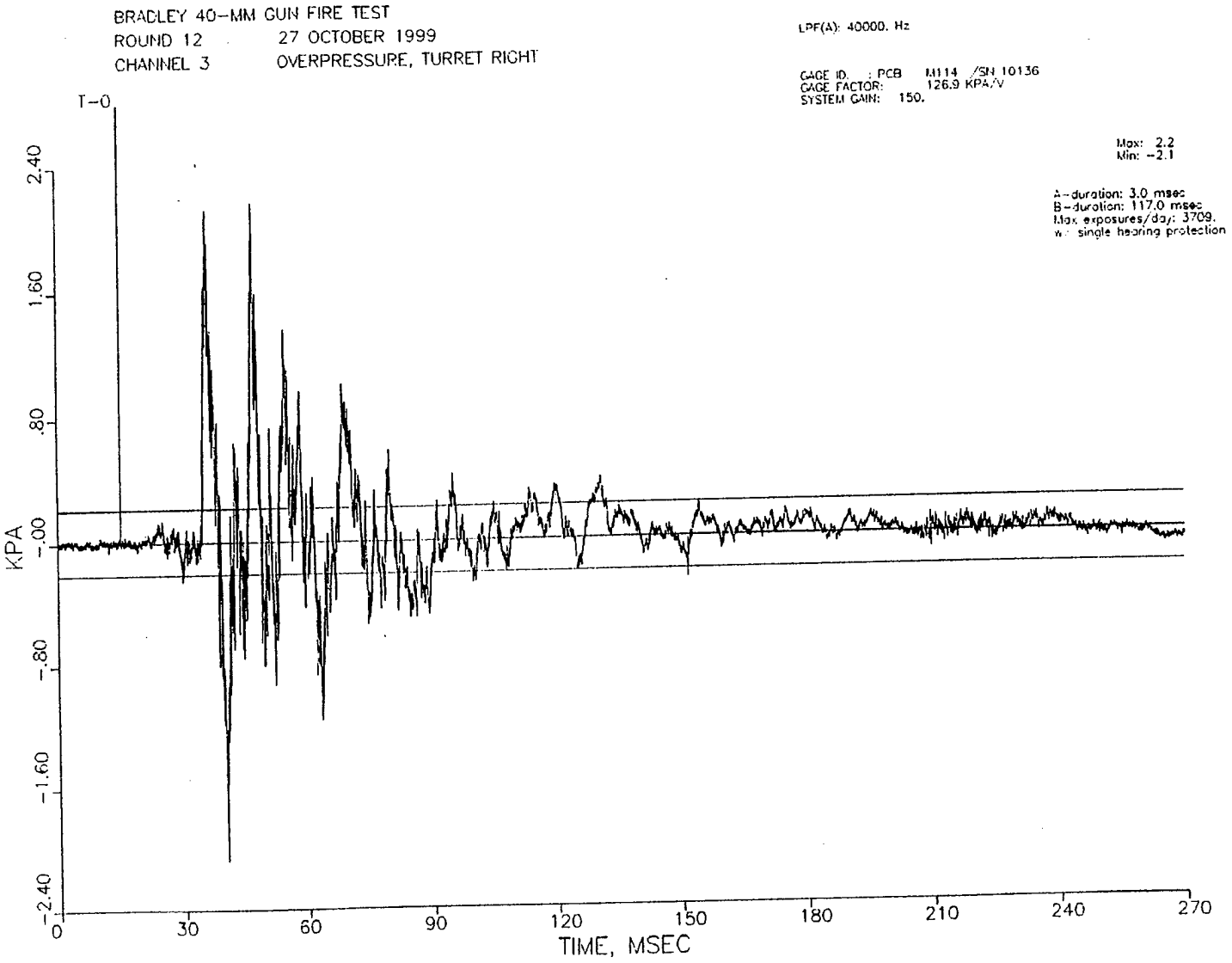

Figure B-47. Overpressure Plot for Shot 12 at the Turret Right Location

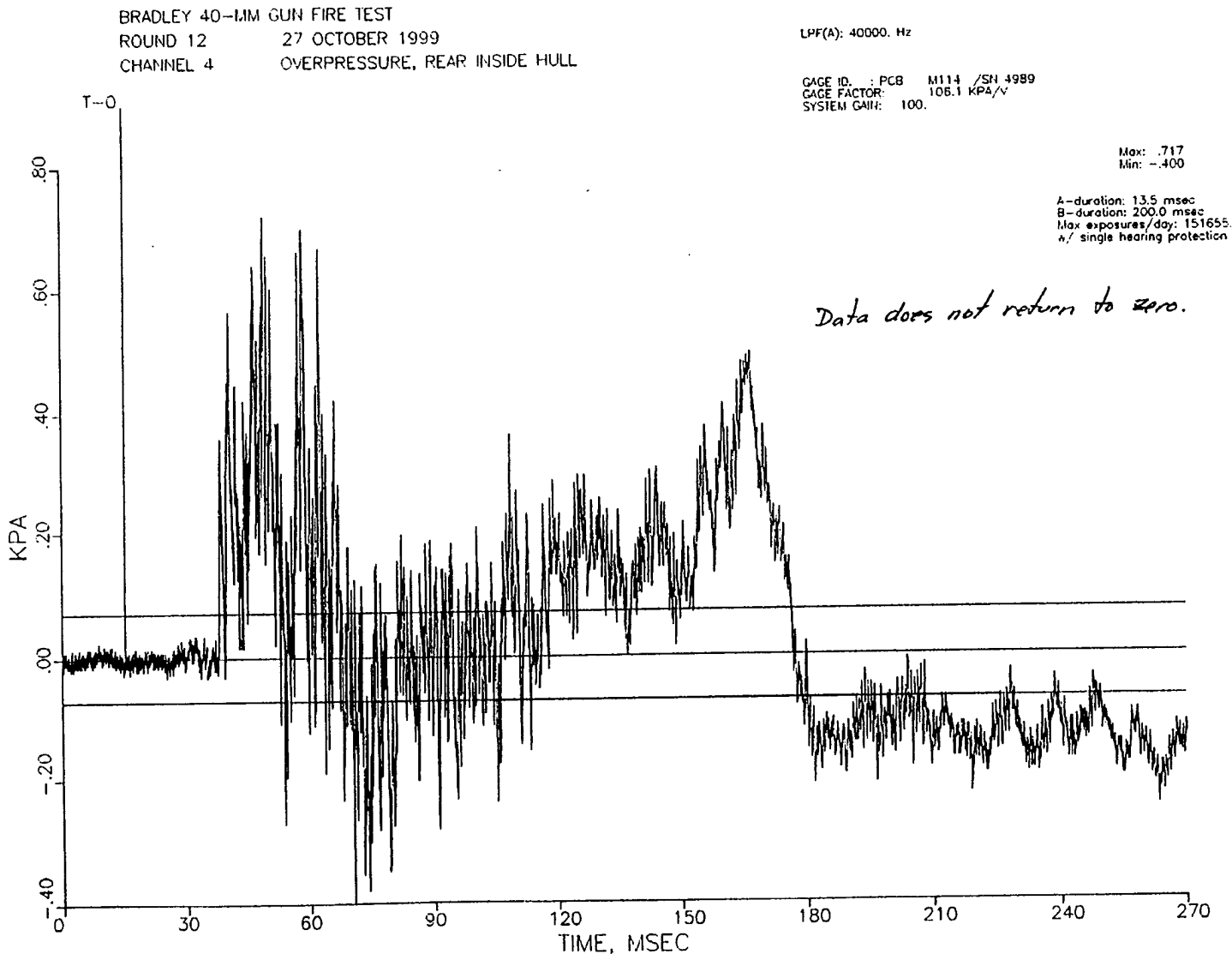

Figure B-48. Overpressure Plot for Shot 12 at the Rear Crew Area Location

APPENDIX C

INDIVIDUAL SHOCK RESPONSE TIME PLOTS

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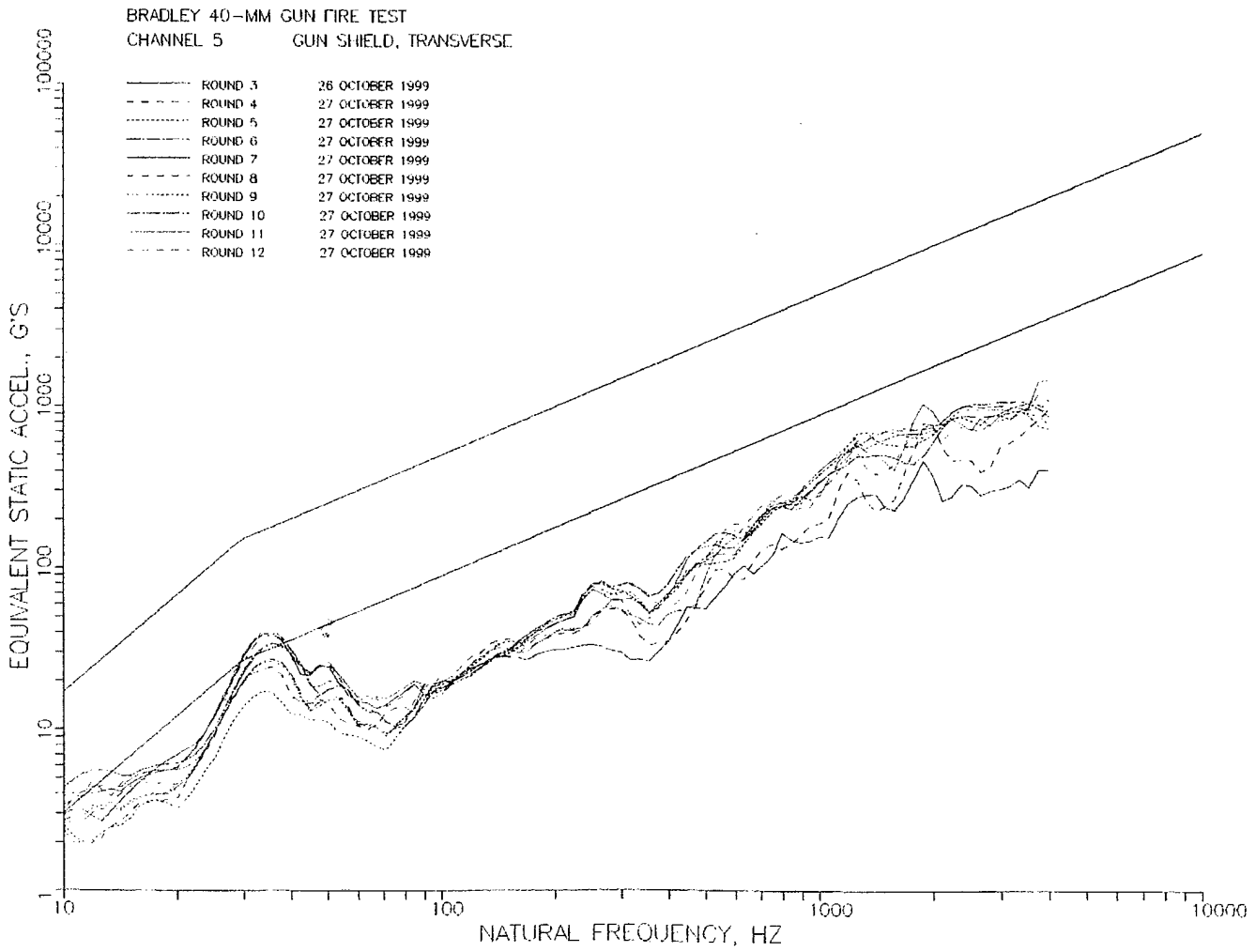

Figure C-1. Shock Response Time for all Shots at the Gun Shield Location (Transverse)

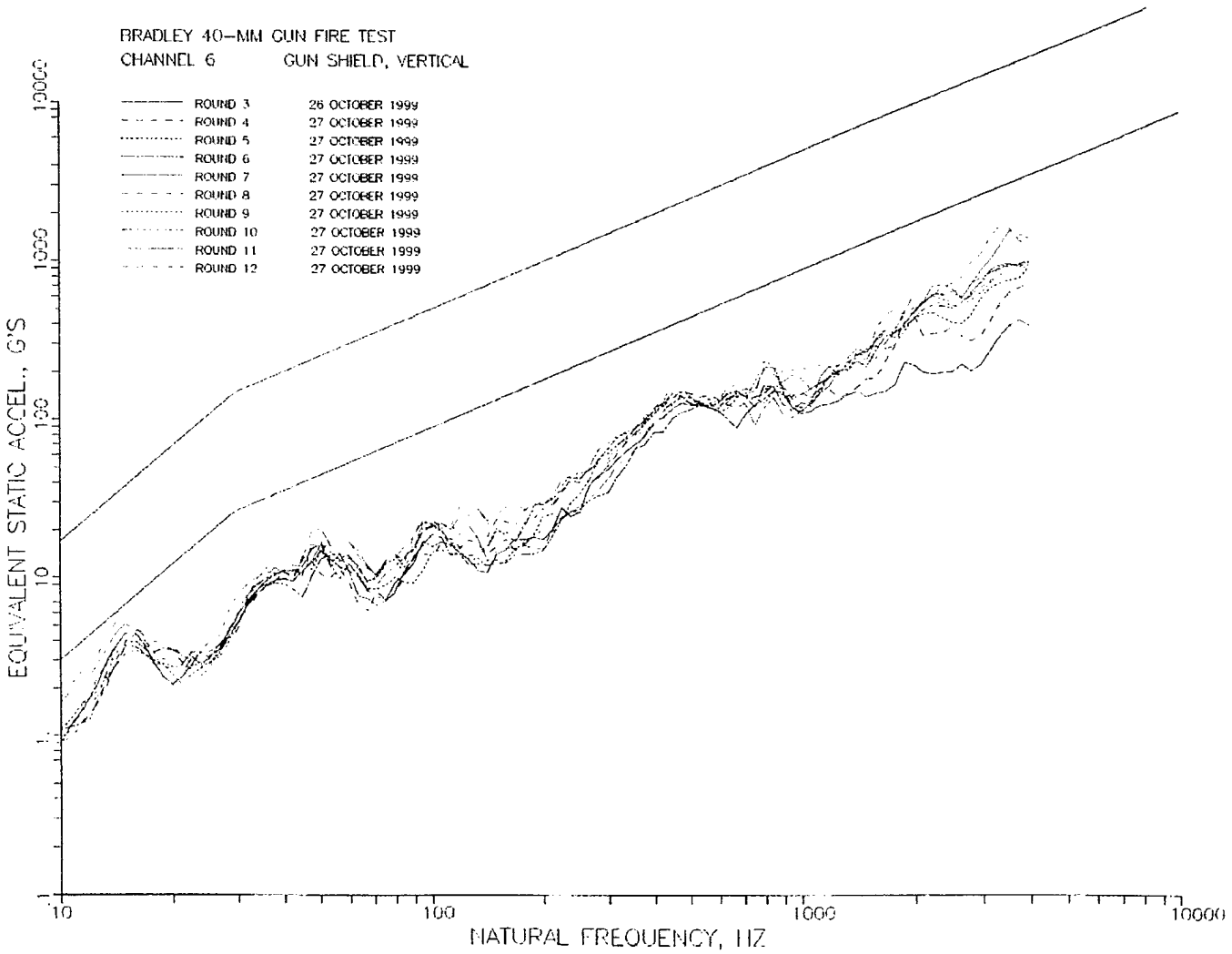

Figure C-2. Shock Response Time for all Shots at the Gun Shield Location (Vertical)

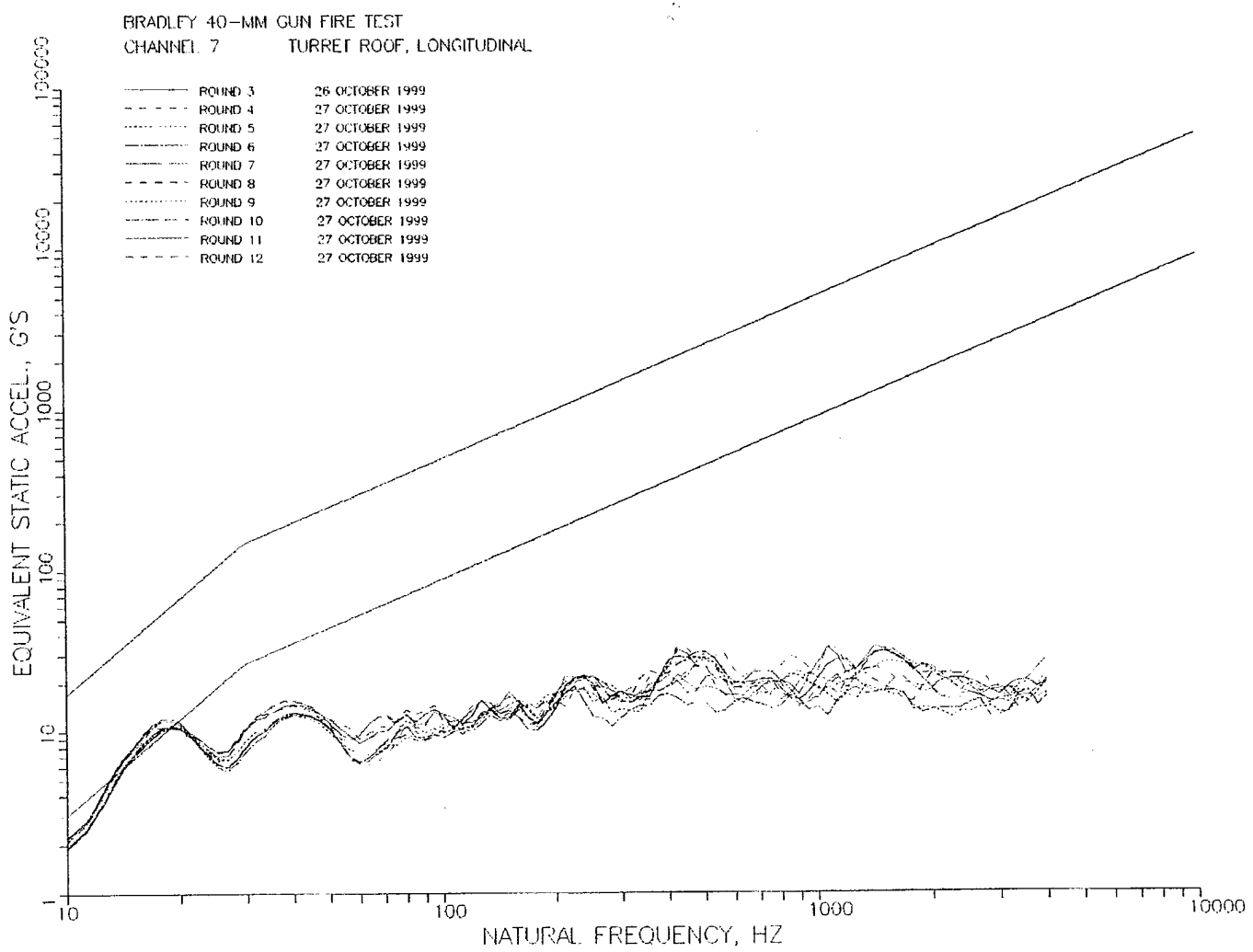

Figure C-3. Shock Response Time for all Shots at the Turret Roof Location (Longitudinal)

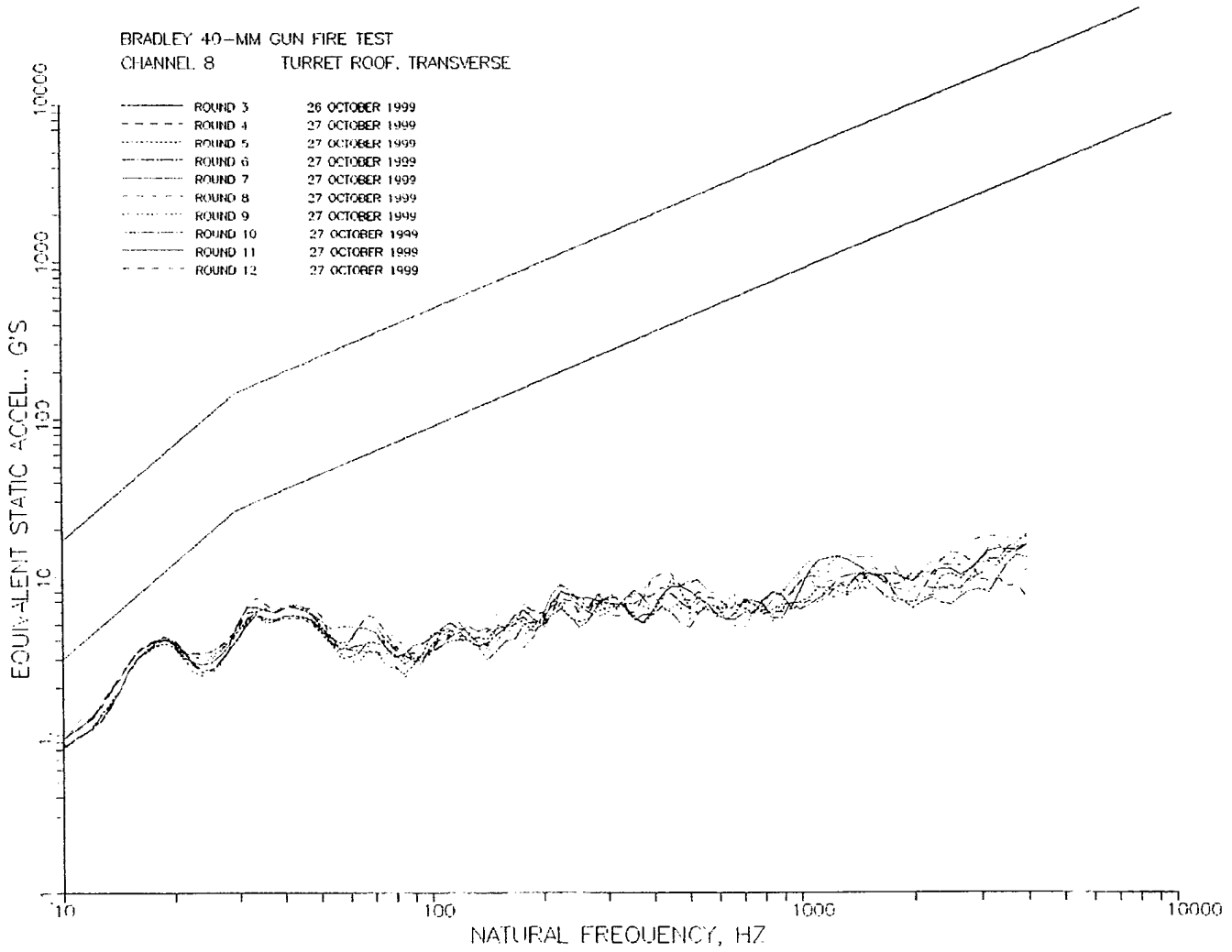

Figure C-4. Shock Response Time for all Shots at the Turret Roof Location (Transverse)

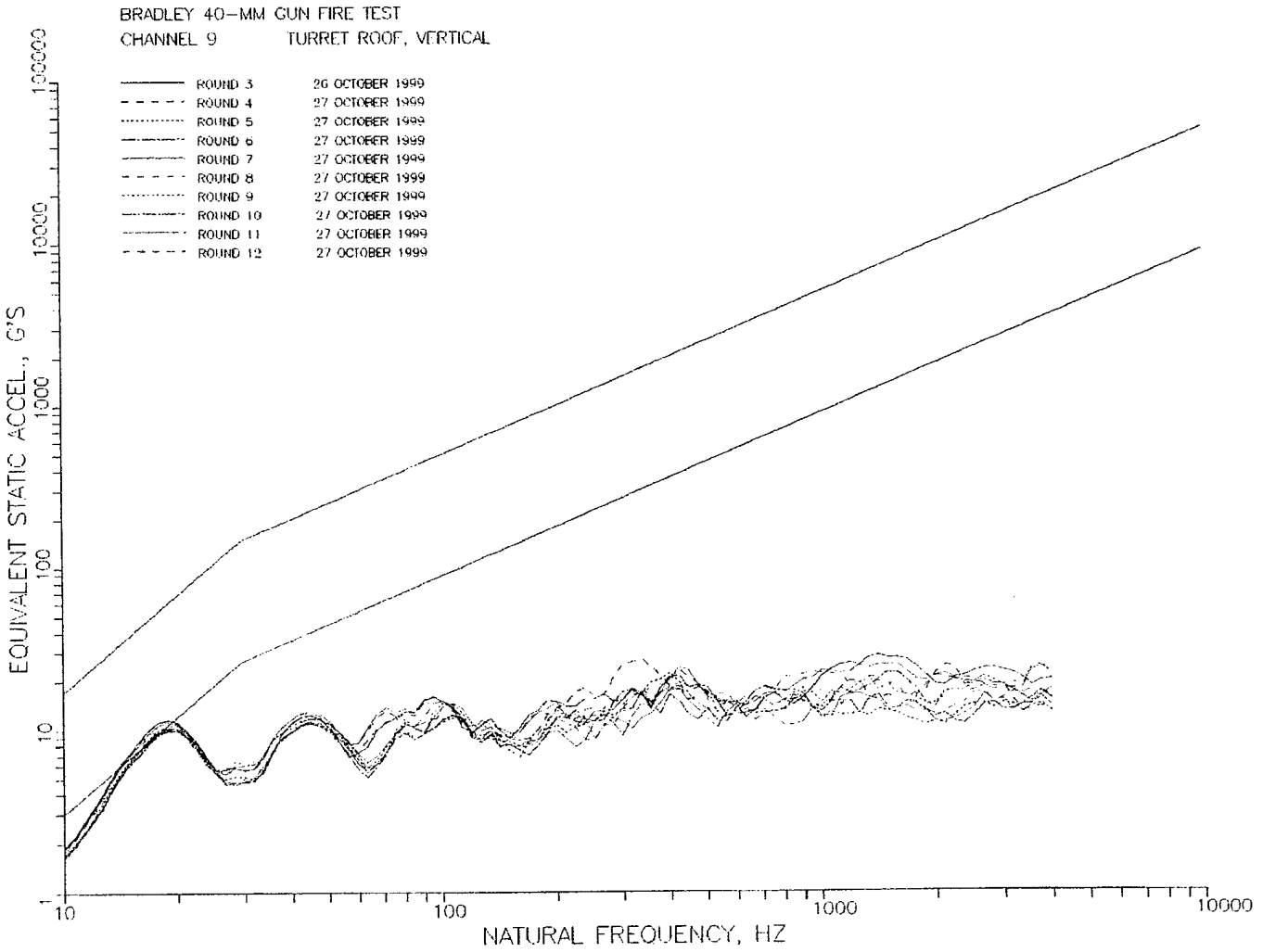

Figure C-5. Shock Response Time for all Shots at the Turret Roof Location (Vertical)

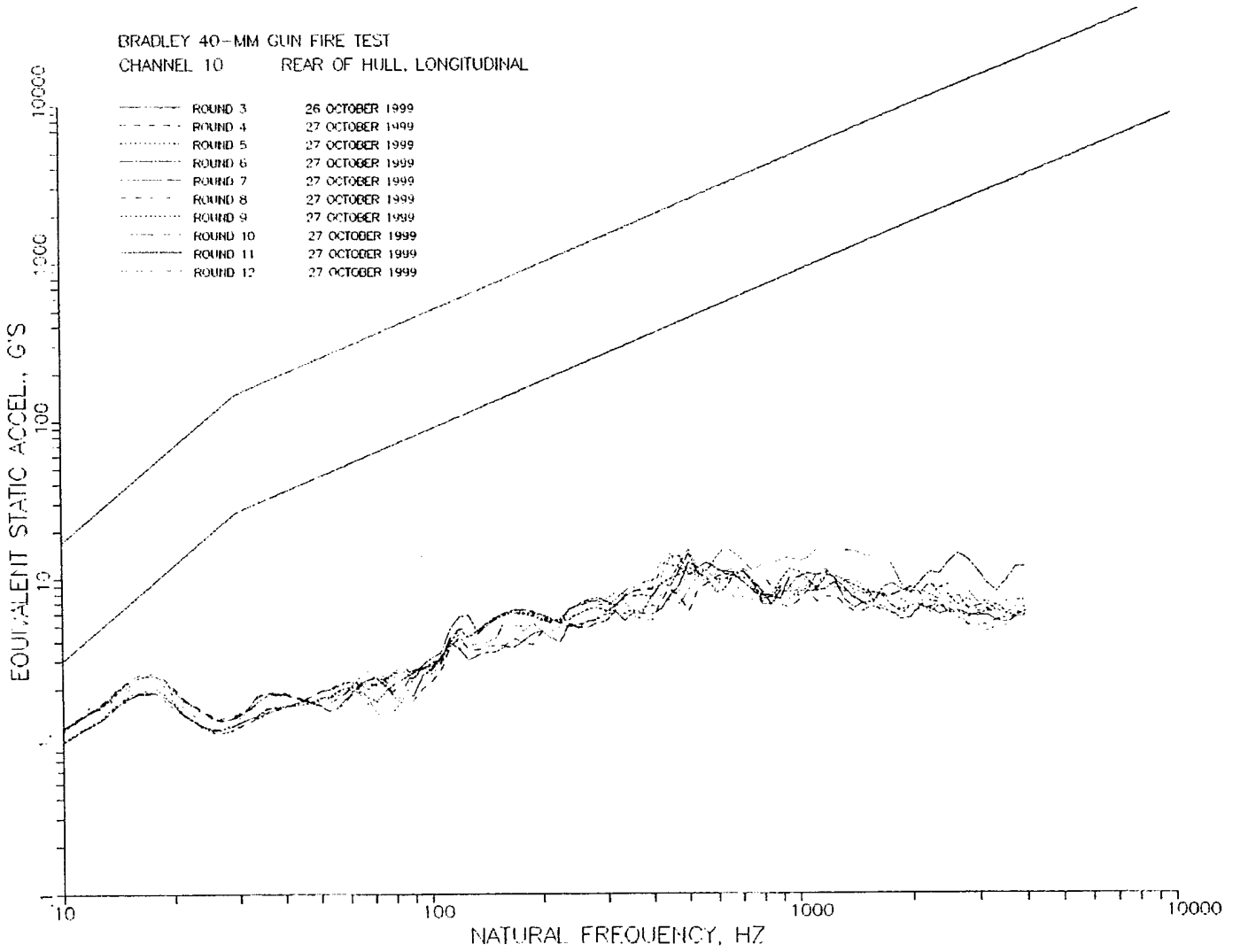

Figure C-6. Shock Response Time for all Shots at the Hull Rear Location (Longitudinal)

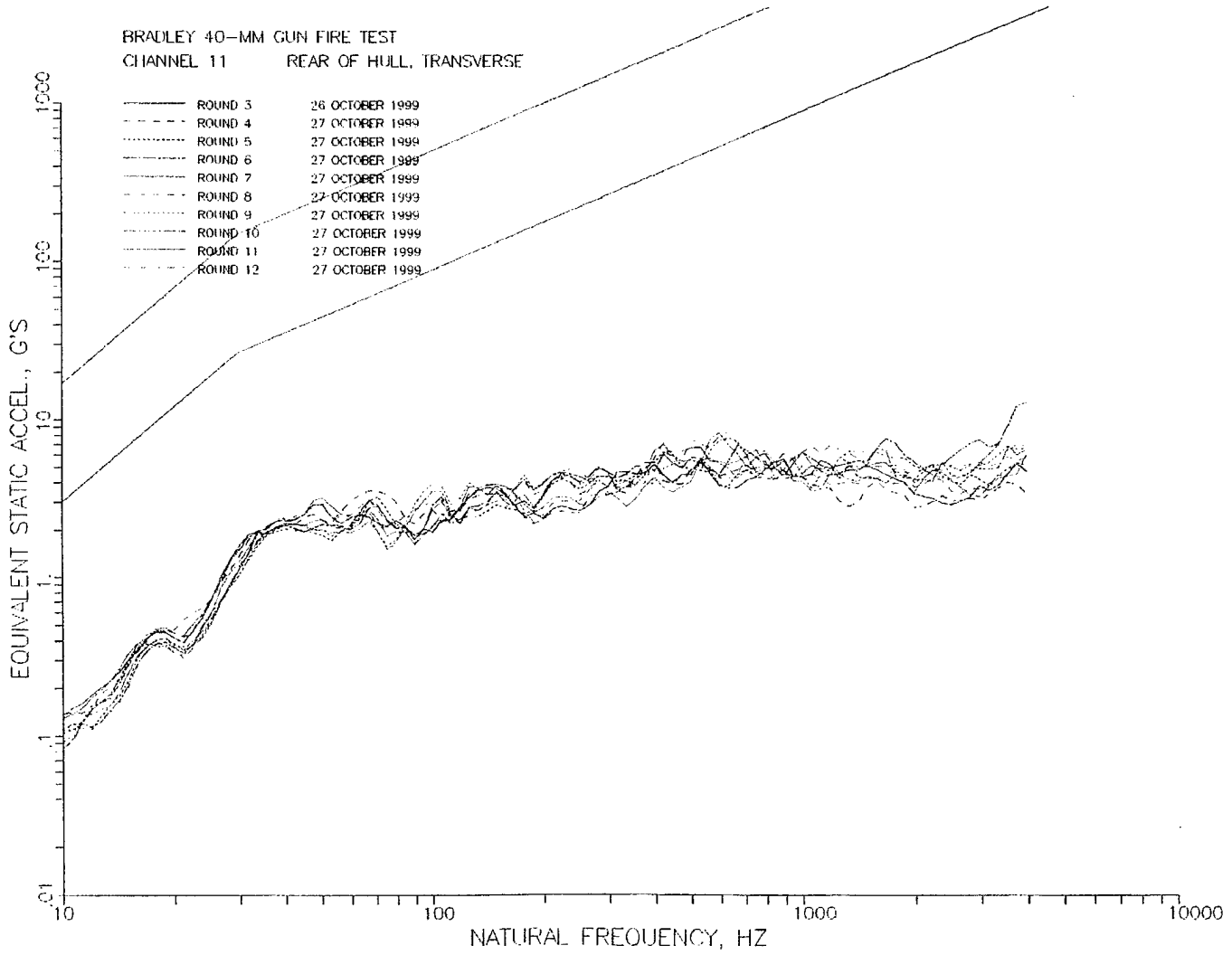

Figure C-7. Shock Response Time for all Shots at the Hull Rear Location (Transverse)

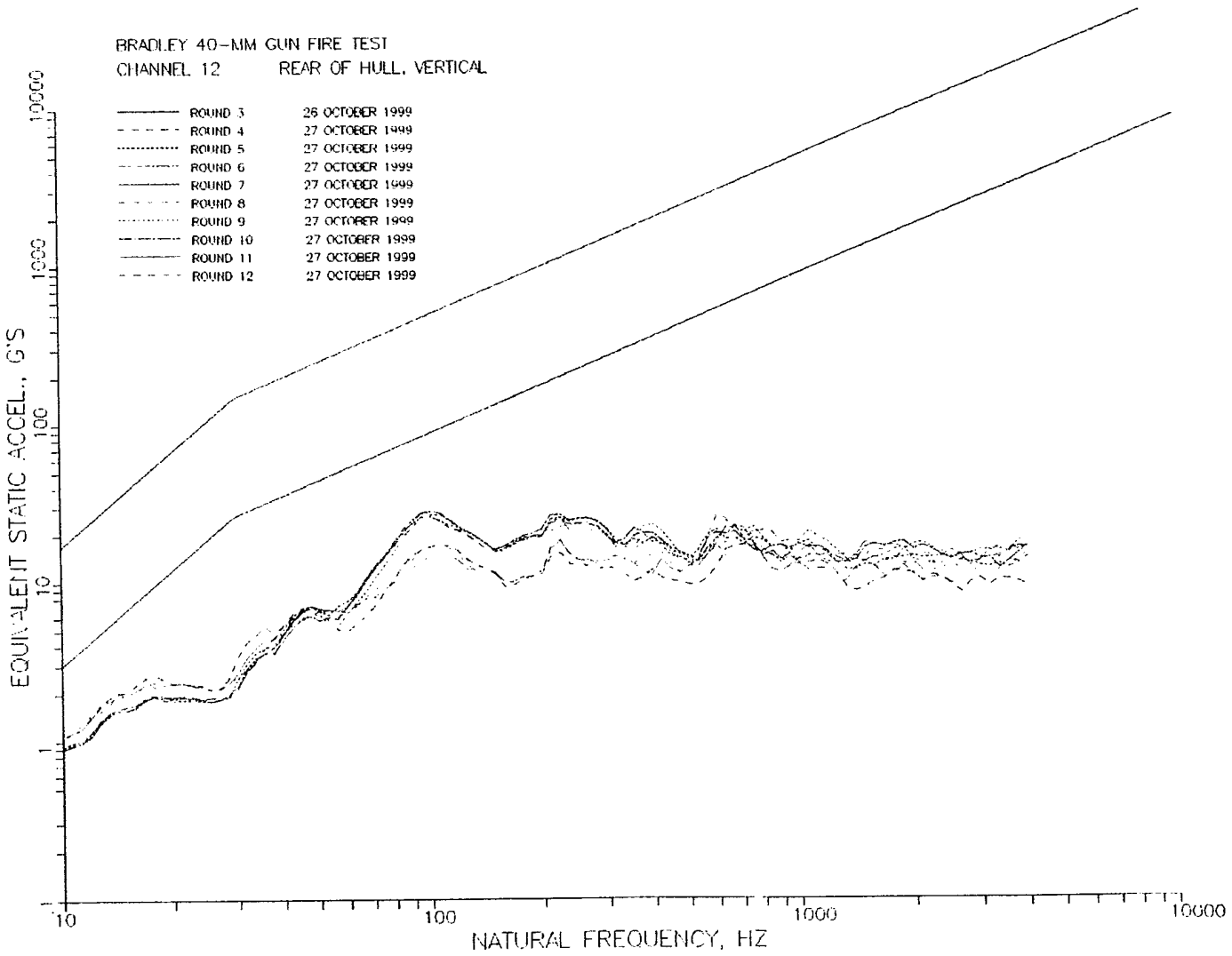

Figure C-8. Shock Response Time for all Shots at the Hull Rear Location (Vertical)

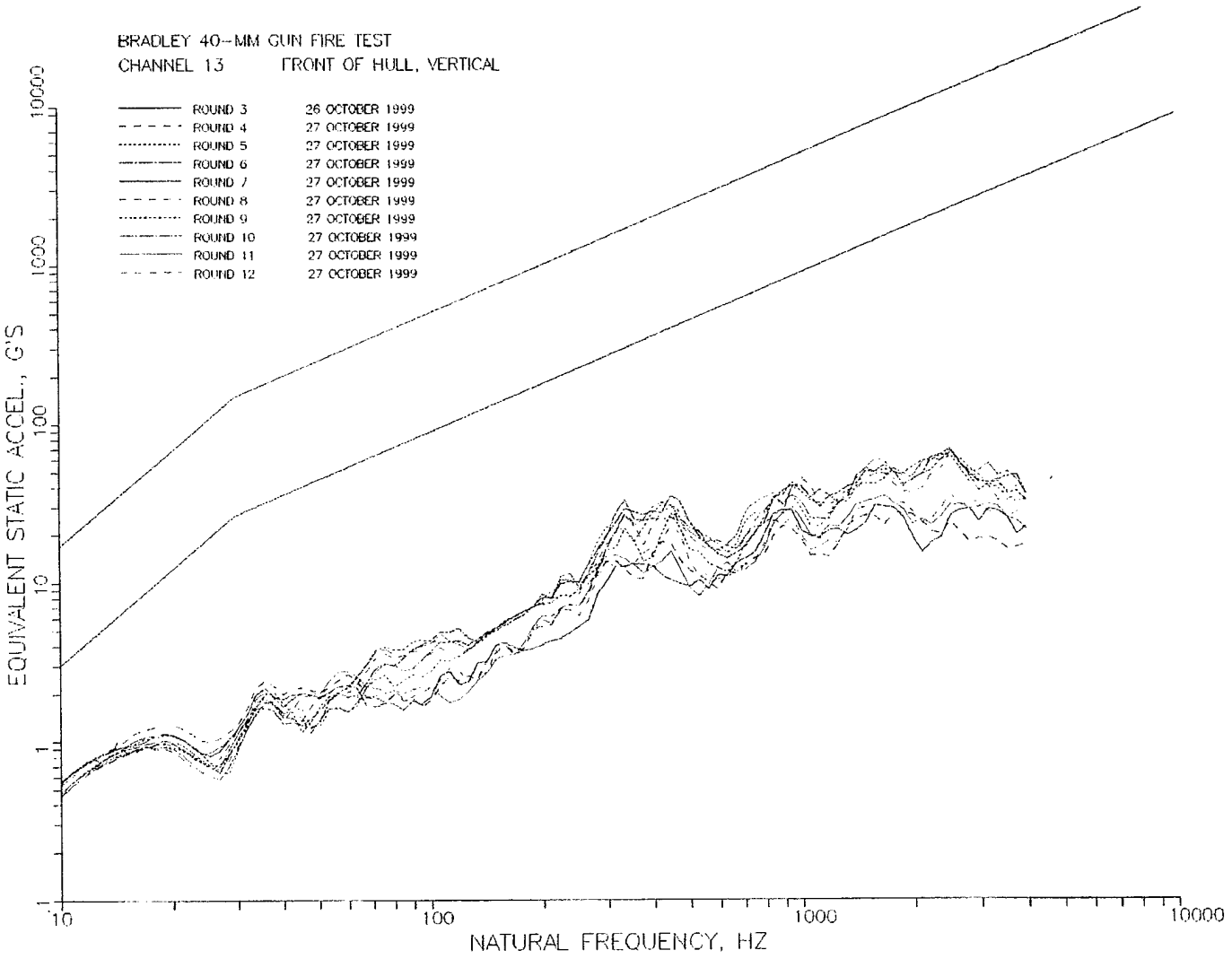

Figure C-9. Shock Response Time for all Shots at the Hull Front Location (Vertical)

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13. ABSTRACT *(Maximum 200 words)*

The capability of off-the-shelf medium caliber ammunition has been advertised extensively. As the decision about the main armament for imminent medium caliber platforms approaches, more definitive independent analyses of the advertised systems are being conducted. To increase the current database, an evaluation of the 40-mm cased telescoped weapon system (CTWS) was coordinated between the U.S. Government and CTA International (CTAI), a French-United Kingdom company. The emphasis of this evaluation was the performance of the armor-piercing, fin-stabilized, discarding sabot (APFSDS) projectile. In addition, the pressures inside the Bradley fighting vehicle, where the CTWS was mounted, and shock measurements on the exterior of the vehicle were taken to estimate the effect of the weapon system on the vehicle and the crew. The evaluation of the terminal effects of the APFSDS against selected Senior National Representatives (SNR)-defined range targets is documented in a separate, classified version of the evaluation.

The APFSDS ammunition performed as advertised, with a muzzle velocity of approximately 1640 m/s and a velocity decay of 0.12 m/s/m. These values give the 40-mm CTAI APFSDS a high velocity at the target for typical engagement distances. The measured shock to the vehicle and overpressures within the vehicle during firing all appear to be at acceptable levels for these initial tests.

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